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LHYDROGEOLOGICAL STUDY
LEACHATE AND GAS IMPACTS (STAGE 2)
UPPER OTTAWA STREET LANDFILL
FOR
THE REGIONAL MUNICIPALITY
OF

IRB/MUN



GARTNER
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**Gartner
Lee
Associates Limited**

Consulting
Engineering
Geologists and
Hydrogeologists

Toronto - Buttonville Airport ■ Markham, Ontario ■ L3P 3J9 ■ 416-297-4600


HYDROGEOLOGICAL STUDY
LEACHATE AND GAS IMPACTS (STAGE 2)
UPPER OTTAWA STREET LANDFILL
FOR
THE REGIONAL MUNICIPALITY
OF
HAMILTON-WENTWORTH

URB/MUN

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September 9th, 1980

The Regional Municipality of Hamilton-Wentworth,
Department of Engineering,
71 Main Street West,
Hamilton, Ontario.
L8N 3T4

Attention: Mr. J. R. G. Leach, P.Eng.,
Commissioner of Engineering

Dear Sirs:

Re: Hydrogeological Study - Leachate and Gas Impacts (Stage 2)
Upper Ottawa Street Landfill Site

We respectfully submit our report on the leachate and gas migration study at the Upper Ottawa Street Landfill Site, as requested by the Region.

The report documents the hydrogeological setting of the landfill site, shows its relationship to the adjacent lands, and evaluates the impact of the landfill on the ground and surface water environment at this time. A biological study was carried out on Redhill Creek to augment the geochemical analysis of the surface water. As well, the potential for combustible gas migration from the landfill was assessed. Based on these data, we have provided geotechnical recommendations for the Region to assist with the closure of this landfill, and have outlined a monitoring program for ground water, surface water and combustible gas.

A summary of the report follows for your convenience. Detailed site description, discussion and comments follow in the subsequent sections. Supporting technical data are appended as background and reference material. A series of figures supplements the main body of the report.

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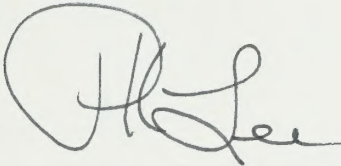
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The Regional Municipality of Hamilton-Wentworth,
September 9th, 1980.

We thank you for the opportunity to serve the Regional
Staff on this interesting project.

Yours very truly,

GARTNER LEE ASSOCIATES LIMITED

A handwritten signature in dark ink, appearing to read 'P. K. Lee'. The signature is fluid and cursive, with a large loop at the beginning and a long, sweeping tail.

P. K. Lee, M.A.Sc., P.Eng.,
Consulting Engineering Geologist

DEJ/sv

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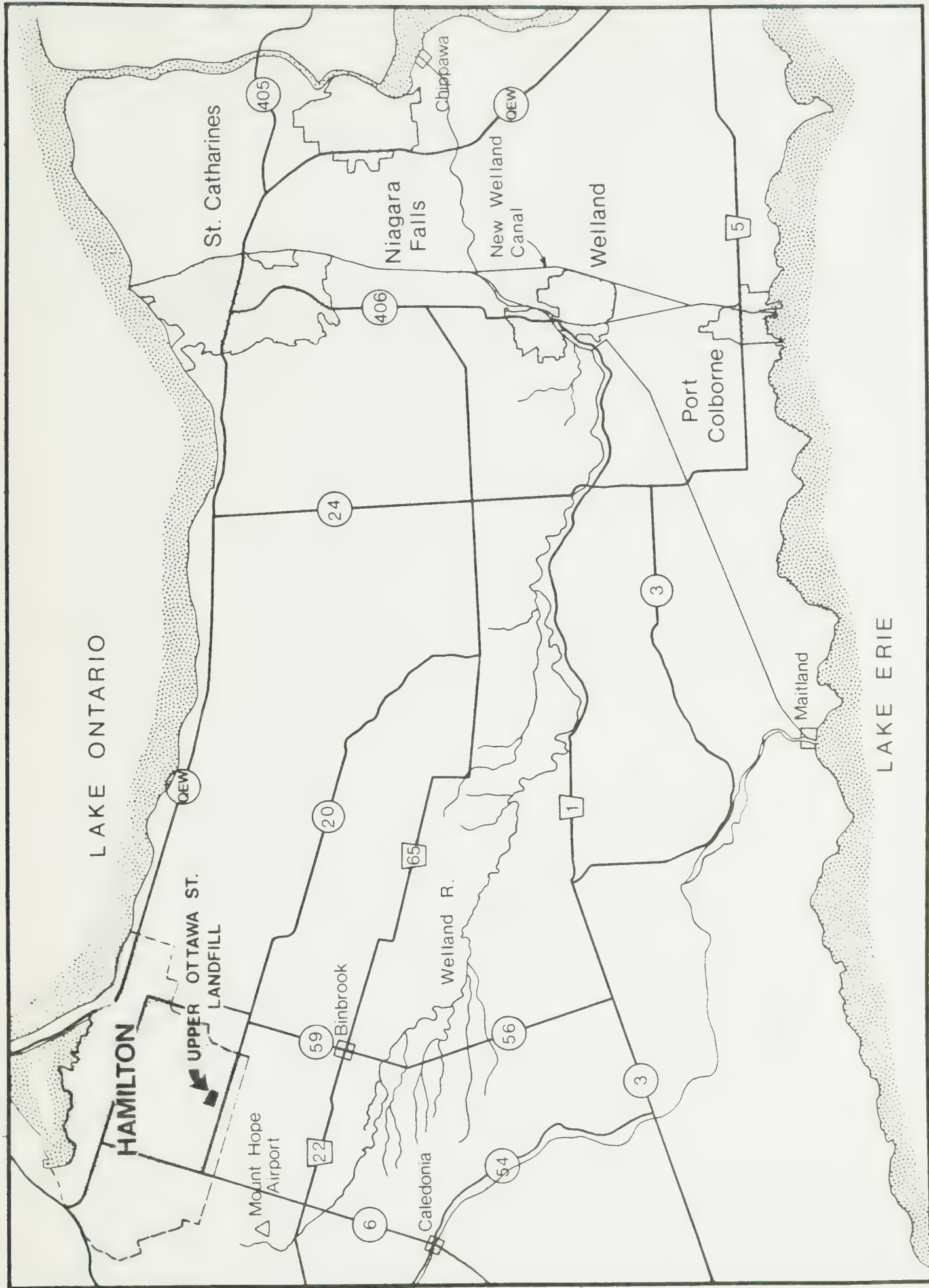
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SUMMARY

A study incorporating field drilling, monitoring and laboratory testing has been carried out on and adjacent to the Upper Ottawa Street landfill site. Surface waters of Redhill Creek have been sampled and tested chemically and biologically for comparison with the ground water both upstream and downstream. We have also carried out an investigation for the possible migration of methane gas.

The landfill site is a mounded structure in which domestic and industrial solid wastes have been placed in lifts to reach thicknesses of between 80 and 90 feet. Industrial liquids have also been disposed of there in the past. The surrounding lands are a clay plain in which the slowly permeable subsoils are often less than 10 feet deep over dolomite bedrock, that forms the caprock of the Niagara Escarpment. Ground water has mounded in the base of the waste and hydraulic gradients cause fluid flow out of the waste into the bedrock. Water velocities in the bedrock are 100 feet per year or less with flow via fractures. The fill occupies the old floodplain and original channel of Redhill Creek and the waste directly overlies the rock where investigated.

The study shows that leachate is being created (at an annual average rate of $35 \pm$ gpm) by this mounded landfill. Of this amount about half exfiltrates into the dolomite bedrock of the area and migrates off site to the north, east and south in the rock joints and bedding planes. The M.O.E. has indicated that there is no known ground water use in the vicinity of the landfill. Contaminant concentrations decrease away from the fill and the plume trends off towards the Escarpment. At this time no surface re-entry or breakout has been observed and the contaminant plume is confined in the rock. This plume has typical chemical properties of landfill leachate. A hardness halo has formed around the site as a result of reaction of the leachate with the rock. Organics are also present; however, no PCB's were encountered in the ground water. Many elements meet M.O.E. drinking water objectives.

Some of the leachate is entering Redhill Creek which contacts the waste along its northern boundary. The creek has been affected locally both from a chemical flux and biologically. Improvement was evident downstream of the site. The creek bed both up and downstream of the landfill provided the only samples where PCB's were detected. The source is suspected to be upstream of the site but has not been identified.

Methane gas, which is generated in the decomposition process, is vented in the fill itself. Therefore no migration of methane in the subsurface was encountered. The potential for migration to the west and south exists especially if the water table drops.

The highlights of the recommendations presented in the report are:

- to carry out proper closure as soon as practical
- the necessity for an on-going monitoring program for ground water, surface water and gas
- the provision for leachate collection toe-drain system around the landfill and discharge to a suitable facility, probably the sewer system
- the provision for erosion prevention measures along Redhill Creek
- the more complete characterization of leachate in the rock - organics, pesticides
- the delineation of the source of PCB's upstream of the landfill in the creek sediments
- the provision for final cover, grading and vegetation to reduce leachate generation
- the prevention of future water taking from the rock of the area to be enforced by municipal regulation
- continuous review of on-going monitoring data and continued vigilance for re-entry of leachate back to the surface.

1.0 INTRODUCTION:

1.1 BACKGROUND:

The Upper Ottawa Street landfill site will be closed and final rehabilitation measures carried out in the near future. As with all landfills, concerns have arisen with regards to the impacts of potential leachate migration and methane gas effects and the need for mitigating measures. To help in the assessment of these conditions two hydrogeological studies have been carried out by our Firm.

In the fall of 1978 Gartner Lee Associates Limited undertook a preliminary hydrogeological study and the results were reported in February of 1979 (Report 78-119). Our report was used to identify concerns and potential problems related to leachate and methane gas based on literature search data, field surface mapping and airphoto interpretation. One of the recommendations was that a subsurface study should be carried out to confirm the suspected impacts outlined by this feasibility planning study.

The present assignment, reported herein (Report 79-78) describes the follow-up subsurface leachate and gas investigation. We were commissioned by the Region in August 1979 to carry out this work under their Purchase Order R29775.

The purpose of our study 79-78 is four-fold.

- i) To establish the existing hydrogeological setting and show the relationship of the waste to the geology, soils, surface water and ground water.

- ii) To assess the impact of the landfill with respect to leachate and gas migration.
- iii) To provide preliminary design parameters and recommendations with regards to remedial measures, closure considerations and future monitoring aspects.
- iv) To address any other concerns brought out in the study, their scope and extent, and the need for further investigation.

This study is based on a field drilling, sampling, monitoring and testing program. We have incorporated all of the data from our preliminary study (78-119) and some information from the report of the Ministry of the Environment entitled "The Effects of the Upper Ottawa Street landfill on Redhill Creek", dated November, 1978.

1.2 STUDY TECHNIQUES:

This study was carried out as a staged program.

Stage 1: Boreholes were drilled at the 10 sites shown on Figure 1, "the Site Plan". The overburden soils were augered and disturbed soil samples were taken and classified by the field hydro-geologist. The bedrock was diamond, drilled and NX core was retrieved for geological logging and to establish stratigraphic details. In selected holes drilling into the rock was advanced by tri-coning techniques. Selected soil samples were tested in the lab to assess their physical properties and classification.

Ground water monitors were installed in all boreholes. A piezometer, with an 18 inch long intake screen, was placed in the hole, in the bedrock, sand-packed and back-sealed by a plug of bentonite clay. In some holes multiple piezometers were set with the use of a second hole to facilitate proper monitor placement. Standpipes were also installed at each location and these pipes were slotted throughout their length. The static water level in the piezometers was used to measure the piezometric pressure head at the intake depth of water in the fractures and beds of the bedrock aquifer. This unit also provided a sampling point of ground water for testing of chemical quality. The standpipes were used to measure the depth of the water table or zone of saturation and in turn were also used to obtain shallow ground water samples. Since injected water is used in the diamond drilling process it was necessary to remove this by bailing and/or pumping the monitors several times. This development of the installations took place over an 8 month period.

Field testing of the installations was done to measure the in-situ permeability of the subsurface units. At the end of drilling and before monitor installation, pressure packer tests were undertaken. During the field work, slug tests were done on the piezometers to determine the permeability of the formation in the vicinity of the intake screen. This provided a further determination of the ability of the subsurface materials to transmit fluids, i.e. their coefficient of permeability. The Region's staff provided surveyed locations and elevations of the boreholes and monitors. Details of the boreholes and observed geologic materials can be found in Section A of the Appendix and data for the ground water monitors are contained in Section B.

Gas monitors were installed in 6 boreholes in locations as shown on Figure 1, Site Plan. The holes were fitted with slotted pipes, backfilled with crushed stone and sealed at ground level with concrete. Details of these holes GM-1 to GM-6 are shown in the Appendix, Section A. These monitors were developed, sampled and tested in-situ with a portable combustible gas detection unit. Results are tabulated in Section D of the Appendix.

Our staff traversed Redhill Creek and studied the surface water and sediment quality on October 31st, 1979. Surface water samples were taken at stations SW-1 through SW-5 as shown on Figure 1*. Bottom sediment samples were also obtained at Stations SW-2 and SW-4 and samples were sent to the Hamilton-Wentworth Regional laboratory for testing. The special analysis for the detection of PCB's on sediments was sent to the Peninsula Chemical Analysis labs. Our biologist collected bottom fauna samples at each of the five stations. We then separated the organisms from the residual detritus at our offices, preserved and classified these to the most practical taxonomic level. At each station observations with regards to condition of the stream (odour, colour, bottom staining, flow rates etc.) were recorded. Details of the surface water quality are documented in Section C of the Appendix.

Ground water samples were obtained by pumping and/or bailing monitors after their development. At that time the electrical conductivity was measured in the field. Samples were sent to the Region's laboratory for testing of leachate indicator parameters: pH, hardness, chlorides ion, Total Kjeldahl Nitrogen, iron, phenol, BOD, COD. The results of this testing is shown in Appendix B, Table 5.

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After the data collected up to this point were analysed, a meeting was held on February 8th, 1980, and the results were presented to Regional Staff, the M.O.E. and Proctor & Redfern Limited. It was decided then that further sampling and testing should be done and another borehole drilled.

Stage 2: Another borehole, number 11, was drilled to the southeast of the fill to help delineate the leachate plume in the subsurface in that direction (see Figure 1). As well, another gas monitor GM-7 was installed. Further water samples were taken in April and May 1980 from the monitors at the eleven drill sites and from surface waters from an expanded network of seven stations as shown on Figure 1. The Ministry of the Environment staff took duplicate sets of samples for comparative analysis. Along with the parameters previously tested, an investigation for the presence of PCB's, organochlorine pesticide scans, and a metal scan was carried out. Results are documented in Section B of the Appendix.

Once the results of the follow-up data were available a second meeting was held with the Region and the M.O.E. . This report presents all of these data from the various stages and analyses.

2.0 HYDROGEOLOGIC SETTING:

2.1 GEOLOGY:

The Upper Ottawa Street landfill is situated on the gently undulating glacial till - limestone plain above the Niagara Escarpment. Figure 2*, the Physical Setting, shows the surface geometry and relationships of the various landforms and physical units identified.

In general, the subsoils are a complex mix of glacial till and glaciolacustrine clays with gradational contacts both laterally and vertically. This drift is thin, often less than 10 feet deep except in the moraine located just to the north of the landfill, across Redhill Creek, where soil depths were found to be about 40 feet.

The bedded dolomite bedrock of the Guelph Lockport Formation forms the caprock of the Escarpment and underlies all of these glacial soils. The surface of the rock slopes towards the east in the site area, i.e. towards the Escarpment. A minor rock scarp, which is now buried by the waste, trends northwest and southeast as shown on Figure 3, Bedrock topography. Along the present Creek channel bedrock outcrops are common.

The lands are drained by the main channel and a tributary of Redhill Creek. Surrounding urbanized areas are serviced by storm sewers. Redhill Creek itself is in a concrete section upgradient from the landfill, i.e. west of Upper Ottawa Street. The Creek goes over the Escarpment at Albion Falls to the east.

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The landfill site covers the former Redhill Creek floodplain, parts of the original creek channel and an excavated area extending to Stone Church Road. The creek was relocated north of the fill to its present course and its south bank abuts the waste as shown on Figure 2. The waste, a mix of domestic and industrial solid residues, has been placed in a series of lifts to form the mounded structure, as shown on cross-section A-A' and B-B'. Our drill holes encountered depths of waste up to 84 feet deep with pockets of construction and demolition and foundry sand wastes as well as garbage. It is reported that industrial liquids were also disposed of at the site and three waste fixation lagoons are located on the surface of the fill (see Figure 2), remains from a now defunct operation. It appears that the daily cover for the fill was the silty clay soils common to this area and the putrescibles of the waste were observed in various states of decomposition. Foundry sand and fine dust were also used. The garbage was saturated generally only near its base but localized seams interpreted as higher perched zones were also encountered. The average coefficient of permeability for this waste mix is in the range of 10^{-4} cm/sec ($120 \pm$ feet per year) although considerable variation is present due to the variability of the waste mixture. For calculation purposes we have used a total porosity value of 35%.

As noted earlier, the subsoils in the area are of glacial till origin (compacted beneath the ice) and also of glacial lacustrine sediment action. Random discontinuous pockets of sand and gravel were encountered by some borings at the bedrock soil interface. The subsoils appear to have been removed before the waste was emplaced. Both types of subsoils are of a silty clay to clayey silt texture and have a coefficient of permeability in the range of 10^{-6} cm/sec to 10^{-7} cm/sec (less than 1 ft./yr.) with a total porosity of 40%, making them slowly permeable. For velocity calculations an effective porosity of 20% has been used. Where the soils are seasonally wetted and dried, the soils above the water table crack

forming a secondary permeability and a loss of 1 to 2 orders of magnitude from the values noted above.

The bedrock is the almost horizontally bedded dolostone of the Lockport Formation that forms the caprock of the Escarpment. Two members were identified from the rock core, the Goat Island and the Gasport. The upper unit is variable, from about 9' to 35' in thickness with thick to thin beds. Its bulk permeability based on both pressure packer and slug tests is about 7 feet per year. The lower unit is thinner (less than 10 feet) and more massively bedded. Its bulk permeability averages about 30 ft./year and the fracture porosity is about 5%. Details are contained in Section A of the Appendix.

A shale unit, the Rochester Formation, underlies the dolomite units. This unit is of much lower permeability, about 1 ft./year, and contains poor quality water.

2.2 GROUND WATER:

The geometry of the water table interpreted from static levels of the standpipes is shown on Figure 4 (Water Table)* using June 1980 data. Generally, the water table or zone of saturation is a subtle reflection of the ground surface contours or topography.

It is evident that the ground water has mounded slightly beneath the waste. Flow is occurring outwards from the waste as shown on Figure 4 with one component towards Redhill Creek. There is also flow from the north towards the creek so that within the shallow flow system the creek is receiving ground water discharge or base flow. The Creek forms a hydraulic boundary for the shallow flow system. A ground water divide also exists beneath the fill resulting in outflow as well to the south and east away from the mound.

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Figure 5 illustrates the geometry of the piezometric surface derived from static heads of the piezometers sealed at depth in the dolomite aquifer. By comparing the elevations of the water table (measured in the standpipes) and those of the piezometric surface we can define the vertical component of flow. Beneath the fill we note the downward movement of water into the bedrock, i.e. a recharge condition in the deep flow system within the rock. Redhill Creek is no longer a hydraulic boundary, and the deeper flow passes under the Creek and heads north to northeast away from the landfill. Other components of flow are to the south and east but lands to the west are hydraulically upgradient. Although piezometric details are not known beyond our installations, regional flow will trend towards the Escarpment face, to the east of the site. The lower boundary of flow in the dolomite will be the sound base of the much more slowly permeable Rochester Shale Formation.

Flow in the bedrock is through open joints (fractures) and along near horizontal bedding planes. The velocity of movement is dependent upon the spacing and size of the fracture apertures. As a result significant velocity variations exist over the area leading to a very erratic pattern of fluid movement as water takes the easiest path. The velocity of flow in the rock can be roughly calculated using the modified Darcy equation:

$$V = \frac{k \cdot i}{n} \quad \text{where}$$

V	=	flow velocity
k	=	hydraulic conductivity or coefficient of permeability
i	=	hydraulic gradient
n	=	effective porosity

Velocities of about 100 feet per year have been calculated for flow within the dolomite bedrock. This means that water entering the flow system in the rock beneath the fill will travel at the approximate rate of 100 feet per year beyond the site boundaries to the north, east and south.

2.3 SURFACE WATER:

The landfill site and surrounding lands are within the Redhill Creek watershed as shown on Figure 7 contained in Section C of the Appendix.

The watershed encompasses a catchment area of about 20 square miles and is drained by Redhill Creek and its tributaries. The head waters of this system are on the till plain of the plateau-like lands above the Escarpment in the area of Upper James Street (Hwy. 6) and Stone Church Road. The Creek passes over the Escarpment at Albion Falls and eventually discharges into Hamilton Bay near Burlington Street. Part of the watershed has been urbanized and serviced by storm sewers. On the site itself the mound forms a surface divide with almost half of the run-off going to the creek and with the remainder on the south and west being picked-up and carried via ditches to the storm sewer. That section of the creek directly upstream of the landfill is carried beneath the urbanized area in a piped underground system.

Unfortunately there are no stream gauging systems above the Escarpment for this creek to provide records of flow data. The 1978 M.O.E. study estimated low summer flows to be between 1 and 2 cubic feet per second (375 to 750 gpm). This low flow may represent close to base flow conditions, i.e. flow due to ground water discharge with little actual surface run-off. During October we estimated surface flow in the creek to be about 6 cfs. Maximum flows

resulting in the highest dilution potential would be during the spring. Worst conditions would be those of the summer as noted above.

The channel of the creek in the site area is predominately within dolomite bedrock. Mapping of this rock in the creek showed that thin sediment zones were often discoloured and iron staining was commonly observed along with leachate springs.

2.4 CLIMATE AND WATER BUDGET:

We have analyzed the long term average annual climatic data from the station at the Mount Hope Airport to estimate the amount of infiltration of precipitation that can be expected in this area. The actual data available for the 1979 study period was also reviewed. Evapotranspiration losses back to the atmosphere were calculated by the Thornthwaite method. These data are shown visually in the Appendix, Section C. Figures 10 to 12 illustrate the average long term conditions and Figures 13 to 15 show actual measured figures for the study year 1979.

On the average about 31 inches of precipitation falls in the area and about 20 inches is lost through actual evapotranspiration where the ground cover is vegetated. On the clay plain where vegetation exists about 4 to 6 inches of precipitation infiltrates into the subsurface, on the average and the remainder of the water surplus flows overland as surface run-off. The maximum infiltration of precipitation occurs in the spring and fall and minimums in the summer and winter. In 1979, precipitation was

above average with a water surplus much above normal and evapotranspiration losses minimized because of the cool temperatures.

Since the landfill presently is a non vegetated surface we have calculated that about 14 inches per year of precipitation infiltrates into the waste. This value correlates well with mass balance calculations dealing with ground water flow and chemical ion concentrations. Therefore, a little more than twice as much water infiltrates into the waste than occurs elsewhere in the area.

2.5 WATER USE:

The Lockport dolomite bedrock was used as an aquifer source for drilled water wells. These M.O.E. records were documented in our preliminary study, contained in Appendix E. Two wells surveyed in 1975 and 1980 are shown on Figure 1,* Site Plan. The area is now serviced with piped water and we understand that there is no water taking from wells for domestic purposes according to M.O.E. staff. Figure 1 shows present and proposed trunk water main routes.

* contained in pocket at back of report

3.0 HYDROGEOLOGICAL IMPACTS:

3.1 LEACHATE GENERATION:

The major cause of leachate generation at this site will be the infiltration of precipitation. Our water budget analysis indicates about 14 inches of precipitation probably enters the surface of the waste mound annually. In addition to this, industrial liquids have been placed in this fill in the past. The average leachate generated over the fill is estimated to be in the order of 35 to 40 gallons per minute. The worst condition occurs in the spring months when water held in storage from winter snow is added to the precipitation at a time when evaporation losses are almost nil.

Because of the age and nature of the waste we have assumed that the fill is in a steady state condition i.e. infiltration into the fill equals exfiltration from the base of the fill and the waste is at field capacity, i.e. all of the void spaces are lined with water. As the water percolates through the waste soluble chemical constituents are taken into solution along with suspended solids and bacteria. This contaminated fluid or leachate exhibits a high hardness, significant concentrations of major ions, biological degradation products such as ammonia and Kjeldahl, BOD and COD. The chemical nature of the leachate is shown on Table 2 of our preliminary report appended in Section E of the Appendix. A scan of the analyses from 3 leachate springs shows the variability of the leachate due to the mix of the waste. These values are typical of those derived from other studies that we have carried out on landfills elsewhere. The highest concentrations of contaminants are those within the waste itself and in its base.

3.2 LEACHATE MIGRATION AND IMPACT:

The leachate migrates under the action of gravity and flows vertically down through the waste to the zone of saturation. From that point onward it exfiltrates through the base of the fill and enters the ground water system. Since the borings show little to no soil cover beneath the fill, the leachate then enters the bedrock flow system migrating outward from the fill through the rock joints and beds. A component enters the Redhill Creek in the shallow flow system and the remainder, about 50% of the total or 20 gpm on the average goes deeper into the rock.

Some of the precipitation that enters the fill, however, does not get as far as the water table. This part of the down flow is deflected laterally where lenses of low permeability silt and clay are intersected in the waste and these create a series of perched springs noted along the south west and east slopes of the fill. A second series of leachate springs occur at the toe of the fill and these reflect the true water table.

Details of each of these leachate conditions is as follows:

- 3.2.1 GROUND WATER ASPECTS: The configuration of the water table or zone of saturation is shown on Figure 4 and that of the potentiometric surface of the ground water flow system in the bedrock on Figure 5.* Arrows drawn at right angles to these contours indicate the directions of ground water flow. Leachate migration from the waste would follow these patterns and form a contaminated zone or plume.

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Leachate enters the rock and moves under the influence of a hydraulic gradient through the open joints (fracture) and bedding planes. Contaminated water follows the water table and enters Redhill Creek, where this water discharges as base flow and mixes with creek water from upgradient of the waste. The creek forms a hydraulic boundary to the shallow ground water system so that contaminated water does not go beyond the creek in the soils. A divide exists in the fill so that leachate also migrates to the east and south of the fill, however, lands to the west are upgradient hydraulically and are unaffected.

Deeper ground water movement from the base of the fill is more complex. This system carries contaminants north of the fill where the plume in the rock passes beneath the creek and flows beyond it. As shown on Figure 5 the plume also moves out from the waste towards the east and the south. The velocity of the water flow is estimated to be about 100 feet per year. Most contaminants travel at different rates, some much slower than the water. The chloride ion however, is relatively unaffected and is very mobile in solution. The plume has moved at depth in the bedrock aquifer downgradient well beyond the subject property. At this time the geometry of the complex flow beyond the study area cannot be defined in detail at depth in the rock. The Escarpment however, forms a hydraulic boundary with discharge zones at its face. Therefore, from our knowledge of the regional flow system the plume is moving easterly in the rock towards the Escarpment. Our preliminary mapping encountered no surface discharge of leachate beyond the property or along the Escarpment face.

We carried out sampling and geochemical testing of the ground water from a selected set of monitors. Some of these installations were screened in the waste and others in the rock hydraulically up and downgradient of the fill. A series of chemical indicators were used to investigate the potential contaminant migration. The test results obtained from the Region's laboratory and a single set from the M.O.E. labs (metal, PCB's and organo chlorides scans) are documented on Tables 5, 6, 7 and 8 of Section B of the Appendix. The indicator parameters correlate well with an earlier analysis shown on Table 2 of our preliminary report that is contained in Section E of the Appendix. The sections that follow provide a discussion of the chemistry of the plume.

Borehole 1 is hydraulically upgradient of the landfill and for this reason was considered as a possible source of background data for downgradient comparisons. The Lockport dolomite intersected in this hole has only a thin saturated section in this upflow area. The monitor available for sampling was a piezometer sealed in the rock near the contact of the underlying Decew-Rochester shale sequence. Therefore, test results from BH 1 should be used only as a rough guide for water quality comparisons. As shown on Table 5 appended, this water is hard (1400 to 1800 ppm calcium carbonate) and slightly basic (pH = 7.4 to 7.7). Chloride ion content ranged between 115 and 175 ppm and the presence of metals was noted. For the metals tested all were within M.O.E. guidelines for drinking water except for nickel and lead. Values for Kjeldahl nitrogen, BOD and COD indicate

organic contamination as well from upflow sources.

Samples from BH 2 and 4 (see Table 5 appended) screened with standpipes in the waste and from piezometers in the rock directly below it show waters typical of those related to landfill leachates. For example chlorides are in the range of 2000 ppm compared to the background of 175 ppm upgradient from the fill. Total Kjeldahl nitrogen values were extremely high indicating high nutrients and organics. Conductivities, an indicator of total dissolved solids ranged from 9500 to 24000 micro mhos per centimeter in the leachate.

Downgradient from the fill, monitors tested showed an increase in hardness of the ground water compared to those in the waste itself. This concentration increase of calcium carbonate (CaCO_3) is caused by dissolution. Therefore the CaCO_3 dissolved from the rock elevates this constituent in the waters. We would suspect that several complex reactions are taking place resulting in chemical complexing. The presence of organics as indicated by Kjeldahl nitrogen also further complicates the picture. Heavy metals are also present as indicated by Table 7 of Appendix B. These are all below M.O.E. drinking water guidelines except for nickel and lead which are slightly elevated. Due to the possibility of organic complexing these metal trends are difficult to substantiate.

An organo chloride pesticide scan was carried out by the M.O.E. on water samples from boreholes 9 and 11. The pesticides detected were α BHC, lindane, β BHC, dieldrin, endrin and γ chlordan. Of these α BHC, dieldrin and endrin were at concentrations

above provincial drinking water objectives. These levels are extremely low - a fraction of a part per billion. No PCB's were detected in any of the ground water samples tested.

Downgradient in the flow system from the landfill, chemical concentrations decrease in the plume, probably because of dilution and dispersion in the mixing zone.

3.2.2 LEACHATE SPRINGS: As noted earlier leachate springs have been formed on the sideslopes of the fill and can be classified into two types (i) a perched system and (ii) ground water table discharges.

The perched system is generally found along the south, southwest and southeast fill faces. These appear to be related to the interface of fairly thick cover and foundry sand - demolition waste about 15 feet above the toe. These emanations are picked up in a perimeter ditch and are carried to a sewer.

Water table springs also occur along all of the faces. The most notable of these was observed near the northeast face where the leachate discharge is being dammed up and pumped back upgradient to the sewer along Stone Church Road. Previously this flow entered Redhill Creek.

On the basis of our observations the springs contributed a discharge of about 15 gpm of the 35 gpm total. Their chemistry has been documented in our preliminary report, Table 2, Section E of the Appendix.

3.2.3

SURFACE WATER ASPECTS: Results of chemical analysis conducted on water and sediment samples that we collected from Redhill Creek are provided in Section C of the Appendix. Bottom fauna results at each sampling site are presented in the same section of the Appendix.

On October 31, 1979, concentrations of most chemical parameters increased progressively downstream from the storm sewer outlet (Station 4) past the landfill site, to Station 2 below the railroad bridge. Parameters indicating this trend were conductivity, chlorides, ammonia, total Kjeldahl and phenols. Much of the increase appeared to be the result of a low volume (10 - 15 gpm estimate) flow of highly concentrated leachate from springs discharging to Redhill Creek and just upstream from the railroad bridge on the eastern boundary of the landfill. While concentrations of all parameters were noticeably higher with progress past the site, only the ammonia levels (8 - 14 ppm) appeared to exceed M.O.E. surface water quality objectives and thus presented toxic conditions to fish life. Analyses of sediment samples collected upstream and downstream from the site indicated a doubling of the iron concentrations. Earlier and more recent studies by the M.O.E. have indicated the presence of minor concentrations of PCB's as shown on the lab test results in Table 3. During the period of the study samples taken and tested by an independent laboratory indicated higher levels. (see Table 13). This will require further sampling and testing.

Bottom fauna associations found during the October 31, 1979 sampling run indicated organic enrichment at three sites. Upstream of the site at Station 4, a population of 425 bottom-dwelling organisms per

square foot of creek bed were dominated by pollution tolerant sludge worms (Limnodrilus and Tubifex). Downstream from the site at Station 2 below the railroad bridge, populations increased to 660+ organisms per square foot of creek bed roughly 600 of which were sludge worms of the same group. Partial recovery was evident at Station 1 just upstream from the pond above Albion Falls. The population of roughly 800 organisms per square foot was dominated by facultative forms and detritus-feeders such as the sowbug (Asellus) and the amphipod (Hyallela) suggesting that organic decomposition was active. Adjacent to the site (Station 3) the population was stunted (54 organisms per square foot) and variety was reduced. Growth of filamentous algae was heavy on the bedrock substrate. These findings could just as easily be attributed to the results of natural limitations exerted by the smooth bedrock as to the result of toxic conditions. Unproductive results in a tributary entering Redhill Creek just downstream from the railroad tracks were judged to be a reflection of low stream-flows and an unstable silty bottom.

Surface water samples were collected at the same stations again in April 1980 along with two additional sites - one further upstream and one downstream from Albion Falls, below the Escarpment. Levels of most chemical parameters were similar to those found during October 1979 although concentrations of ammonia and Kjeldahl nitrogen were as much as an order of magnitude lower in surface waters near the site in April 1980. These two parameters were the only ones which appeared to increase with progress downstream past the site. In fact, levels of some chemical parameters such as chlorides and zinc increased between

upstream reference stations (6 & 4) and decreased with progress downstream past the landfill site. Levels of unionized ammonia still exceeded M.O.E. objectives past the site during April 1980.

While Redhill Creek has been and still is affected by leachate from the Upper Ottawa Street Landfill, impacts were localized and somewhat masked by upstream sources. It is thought that recovery of associations of aquatic life from upstream stormwater inputs is delayed by additional loadings from the site.

A major parameter of concern in the vicinity of the site is un-ionized ammonia which during October 1979 was found to be well above provincial water quality objectives. In April 1980, objectives were still exceeded but concentrations were greatly reduced to a level which was almost satisfactory for fish life. The redirection of the concentrated leachate stream from entering Redhill Creek to a nearby sanitary sewer line may have been a contributing factor in this improvement. Concentration decreases down-gradient from the landfill; however, it is suspected that there are sources upstream. This source upgradient and beyond the waste mound has not been determined in the present work.

3.3 GAS ASPECTS:

One of the products of the decomposition of organic material is gas. In a sanitary landfill the two most common gases generated are carbon dioxide and methane, although other gases such as hydrogen

sulfide are often present. Carbon dioxide which is heavier than air mixes with the ground water. The mixing results in an increased ground water hardness, and is generally not a significant concern.

Methane gas is odourless but explosive in concentrations of between 5 and 15 percent methane by volume with air, and thus can be a public safety concern. Since methane gas is lighter than air it will naturally tend to vent by upward movement. Provided the venting is not impeded by a layer of slowly permeable material such as clay or a surficial zone of frost, the gas dissipates harmlessly in the air. When surface venting is impeded the gas will tend to migrate laterally provided there is a porous medium for movement. The ground water table is the lower boundary condition, i.e. methane will only migrate through the unsaturated zone.

No combustible gas was detected in any of the monitors except GM 6. Monitor GM 6 indicated a combustible gas concentration of 90% in October, 1979. The gas was flowing from the monitor under pressure. During the winter months gas concentrations in GM 6 decreased to zero. In April the concentration was at 12.5%.

At the Upper Ottawa Street Landfill, it appears that most of the methane generated, naturally vents through the surface of the fill. This venting can be seen in the form of gas bubbles in the area of leachate springs. However if the natural venting was impeded, the geologic conditions in the subsurface rock particularly west of the site,

are conducive to lateral gas migration. The rock in this area is fractured and these openings could provide an avenue for migration. This is only possible in upper horizons of the rock where it is unsaturated. Some lateral movement was noted in GM 6 where combustible gas was measured at 90 and 12.5 percent at two periods. Thus a potential hazard could develop in the future in this area, and this concern should be addressed.

At the south end of the landfill along Stone Church Road the soils are deeper and are composed of slowly permeable clay and silts. Significant lateral migration is highly unlikely through these soils, even where fractured. Thus the potential hazard for structures along the south side of Stone Church Road is minimized. Monitoring is essential though for confirmatory purposes.

Redhill Creek is a boundary for gas movement and hence the gas cannot migrate beyond the creek. As well, there is no concern for gas migration easterly and south-easterly from the site due to the locally high water level and slowly permeable soils enclosing the waste.

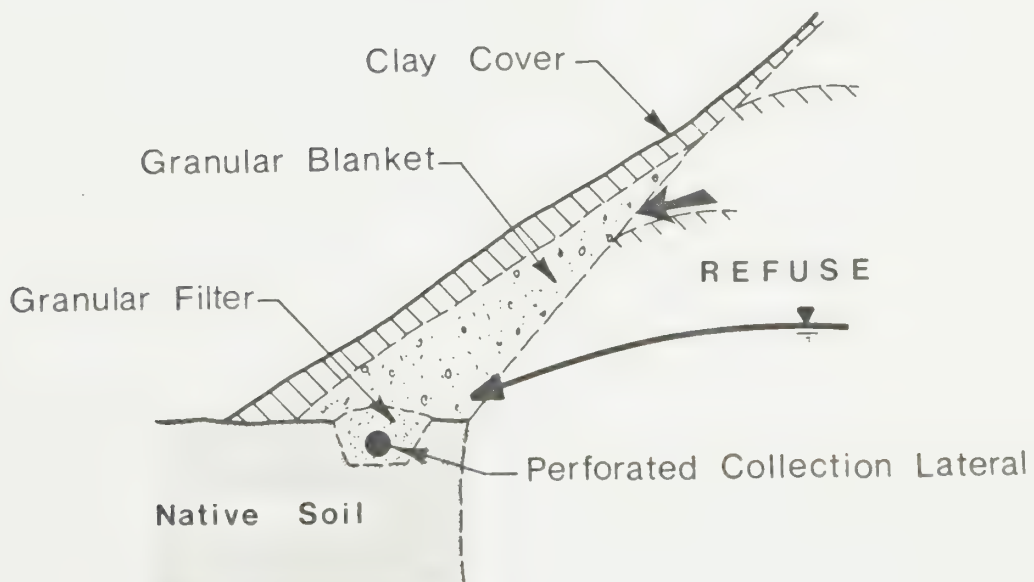
We feel that gas observed bubbling from the creek bed is likely related to natural gas in the rock being vented. It has been verbally reported that this condition existed prior to landfilling. Detailed and sophisticated laboratory analysis would be needed to confirm the origin.

4.0 RECOMMENDATIONS:

4.1 LEACHATE SPRINGS:

Leachate springs are discharging on the landfill sideslopes in the two systems described in Section 3.2.2 . The perched spring system is often seasonal with wet weather flows that migrate down the face to the drainage ditch to be discharged in the sewer along Stone Church Road. The springs of the second system are those caused by the intersection of the ground water table near the toe of the fill and these are perennial. The worst springs observed were at the northeast corner of the landfill where the discharge was being dammed (to prevent entry into Redhill Creek) and was being pumped back-up slope to the Stone Church Road sewer. The chemistry of the leachate springs is documented on Table 2 of Appendix E.

- *We recommend that a toe drain leachate collection system be installed along the west, south and east faces of the landfill. Conceptually, a typical system to deal with both spring systems is shown below.*



- We recommend that the collection lateral be designed for gravity drainage with eventual discharge probably planned for the sewer along Stone Church Road.
- We recommend that a granular filter be designed to surround the pipe and that cleanout pipes should be incorporated to prevent clogging of the system.
- We recommend that a separate system be considered along the east and north east faces. A pumping type system may have to be designed to produce the same results that are now being undertaken at the leachate dam. We would suggest a toe drain leading to a collection chamber and then provision for pumping back-up slope to Stone Church Road be considered. Another alternative might be a deep gravity drained system. The M.O.E. staff should be consulted in this regard. In any event, the present measures should be maintained and monitored in the interim until this is resolved.
- We recommend that M.O.E. staff be consulted with respect to the suitability of the quantity and quality of the leachate to be discharged to the sewer
- Collection measures are not considered to be necessary on the north side of the fill at this time, due to the small number and discharge volume of these springs. However, proper placement and vegetation of the slopes is recommended in this area. This final cover blanket will further minimize this discharge.

4.2

GROUND AND SURFACE WATER:

Leachate is migrating as a plume within the dolomite bedrock to the north, east and south of the site. Concentration of contaminants decrease away from the fill and we understand from the M.O.E. that no water taking from wells downgradient is taking place.

- *We recommend that the contaminant plume in the bedrock be monitored to measure any changes in the water quality that may occur with time. Details are provided in Section 4.4.*
- *We recommend that the prevention of water taking from wells now and in the future be confirmed and that these sources be sealed if this has not already been done.*
- *We recommend that final cover be placed on the fill as described in Section 4.5 to further minimize the generation of leachate and this cover be vegetated as soon as possible.*
- *We recommend that the ongoing monitoring be used to assess the need for interception of the plume in the rock. If testing shows that the concentrations are increasing beyond M.O.E. guidelines, then remedial measures should be considered to capture and collect the contaminated water. Such a system would probably involve purge wells. Such measures would require further extensive investigation and design.*

Borehole No. 1 is being used to gather upgradient samples of water from the rock for background comparison purposes. Since this hole is screened near the Rochester shale Lockport dolomite contact it is not yielding a true background. Water from the Rochester shale is of poor natural chemical quality.

- *We recommend that consideration be made for the drilling of another background quality well either to the north or south of the site but outside the area of the leachate plume.*

Lab test results of the Region's lab and the M.O.E. show differences in their concentrations measured. Any differences in chemistry are related to different sampling times, laboratory testing techniques and detection limits of each laboratory. The significance of these differences are minor and do not alter the interpretations of the impact of the landfill on the ground and surface waters.

The lab testing shows the presence of pesticides even though near acceptable limits, in ground water monitors downgradient of the fill.

- *We recommend that more extensive testing be done to evaluate and confirm the presence of these contaminants and their extent.*

Based on the findings of the present study and the earlier M.O.E. work, the impact on surface water quality is localized.

- *We recommend that on-going monitoring of the creek be carried out as detailed in Section 4.4.*
- *We recommend that the presence of PCB's in the bottom sediments be confirmed and that the upstream source be determined if possible.*

4.3 GAS ASPECTS:

The gas monitors used in the present study show no gas migration at this time. Our analysis shows that the fills naturally vent the gas and the high water table prevents migration.

However there is a potential for gas migration along the west and south of the fills in the future especially once the landfill is final covered.

- *We recommend that the existing monitors be retained and an ongoing program be carried out as described in Section 4.4 to ensure future migration does not become a concern. We recommend additional monitors be placed beyond GM 6 to assist in this regard.*

4.4 MONITORING:

This section of the report discusses a suggested monitoring program to be initiated on the closure of the landfill. The program is divided into three parts - ground water, surface water, and gas - and each part is discussed separately.

4.4.1 GROUND WATER: The present study has assessed the impact of the landfill on the ground water and recommendations were made in accordance with these findings. Leachate will be generated for many years into the future at this facility and will continue to contaminate the ground water in the bedrock. In order to measure any changes in the water quality and to re-evaluate leachate control schemes, a monitoring program is required. The essential elements of the proposed program are as follows.

- Monitor stations should include the following installations

Borehole 1, Piezometer (I)
ground water upgradient and the proposed future installation

Borehole 4, Standpipe (II)
for leachate

Borehole 4, Piezometer (I)
for ground water under the landfill

Borehole 6, Piezometer (I)
ground water north of site

Borehole 9, Piezometer (I)
ground water east of site

Borehole 11, Piezometer (I)
ground water south of site

- The monitor stations should be sampled and tested twice during the next year; November 1980 and May 1981 are suggested.
- A full geochemical analysis should be carried out in a laboratory for conductivity, pH, hardness, alkalinity, chlorides, total kjeldahl, calcium sodium, free ammonia, nitrite, nitrate,

phenol, BOD, COD, sulphate, phosphate, phosphorus, a metal scan, an organochlorine pesticide scan and PCB.

- Water levels should be recorded in all the installations listed on Table 2, Section B of the Appendix in November 1980 and May 1981.
- Proper and complete records should be maintained of all the results.
- Results should be reviewed and analysed by an experienced and qualified professional.
- The monitoring program should be re-evaluated no later than May 1981.

4.4.2. SURFACE WATER: Based on the findings of the present study, the impact of the landfill on surface water quality in Redhill Creek is localized. Although we do not anticipate an aggravation in water quality, we advise that routine monitoring be carried out by the Region for confirmatory purposes. This work would be in addition to the testing program of the Ministry of the Environment currently underway. The following program is suggested:

- Monitor stations be established at locations SW-1, SW-2 and SW-4 as shown on Figure 6, Section C in the Appendix.
- Surface water samples should be collected and tested in November 1980 and May 1981. This work could be co-ordinated with the ground water monitoring program.

- The geochemical analysis should include conductivity, pH, chloride, ammonia, total kjeldahl, BOD, phenol and iron.
- Proper and complete records should be maintained and the results reviewed by an experienced and qualified professional.
- The monitoring program should be re-evaluated in May 1981.
- A second set of sediment samples should be retrieved and tested for PCB. If these results confirm initial testing, then the source should be traced.
- An inspection for surface break out should be continued downgradient, including the Lockport Rochester shale interface along the Escarpment.

4.4.3. GAS: There is a potential for the lateral migration of methane gas both west and south from the landfill. Although there is no present public safety hazard at this time a monitoring program is recommended to assess future gas concerns.

- The gas monitors installed for the present study should be maintained and incorporated into the monitoring program. Two further monitors should be installed west and south of GM 6.
- The monitors should be checked for combustible gas ever month from December to March and ever second month from April to November in the field. A portable combustible gas meter may be used for this purpose.

- Once a year in February, a gas sample should be collected from each gas monitoring station and submitted to a laboratory for detailed analysis.
- Proper and complete records should be maintained and the results reviewed by an experienced and qualified professional.
- The monitoring program should be re-evaluated once per year, unless conditions warrant an earlier modification.

4.5 CLOSURE AND OTHER ASPECTS:

The erosion of wastes and cover along the toe of the north face of the landfill adjacent to Redhill Creek is a problem during high flows.

- We recommend that toe erosion be prevented by the use of a protection system. Several alternatives are available - gabions, rip rap and interlocking blocks or mats.
- We recommend that the protective system be designed for flexibility to deal with differential settlements in the fills. Granular filters should also be used.
- We recommend that the stream hydraulics and potential downstream erosion be considered in the design.

The present landfill surface has a mixed textured cover and is non vegetated.

- Vegetation planting and grading should be considered to reduce erosion over the whole site and steep slopes.

- We recommend that a final cover of slowly permeable soils be placed and graded to reduce infiltration of precipitation. A minimum of 3 foot depth is recommended and provision should be made to vegetate this to promote evapotranspiration. These measures and the provisions for leachate collection are expected to minimize the odour problem.
- We recommend that the area occupied by the former solidification ponds be of high priority for cover and proper grading.

APPENDIX

SECTION A

GEOLOGICAL DETAILS

BOREHOLE LOGS

LIST OF ABBREVIATIONS

PENETRATION RESISTANCE

Standard Penetration Resistance 'N' - The number of blows required to advance a standard split spoon sampler 12 inches into the subsoil, driven by means of a 140 pound hammer falling freely a distance of 30 inches.

Dynamic Penetration Resistance - The number of blows required to advance a 2 inch, 60 degree cone, fitted to the end of drill rods, 12 inches into the subsoil, the driving energy being 350 foot pounds per blow.

DESCRIPTION OF SOIL

The consistency of cohesive soils and the relative density or denseness of cohesionless soils are described as follows:

<u>Consistency</u>	<u>'N' Blows/Foot</u>	<u>Denseness</u>	<u>'N' Blows/Foot</u>
Very Soft	0-2	Very Loose	0-4
Soft	2-4	Loose	4-10
Firm	4-8	Compact	10-30
Stiff	8-15	Dense	30-50
Very Stiff	15-30	Very Dense	> 50
Hard	> 30		
W.T.P.L.	-	Wetter than Plastic Limit	
D.T.P.L.	-	Drier than Plastic Limit	
A.P.L.	-	About Plastic Limit	

DESCRIPTION OF ROCK

$$\% \text{ Recovery} = \frac{\text{Total Length of Core Recovered/Run}}{\text{Total Length of Drilling Run}} \times 100$$

TYPE OF SAMPLE

SS	-	Split Spoon
AS	-	Auger Sample
NX	-	2.16" ϕ Rock Core
▲	-	Water Table Monitor (Standpipe Tip)
●	-	Piezometer Tip

BOREHOLE NO. 1

PROJECT NAME UPPER OTTAWA STREET LANDFILL SITE

PROJECT NO. 79-78

CLIENT REGIONAL MUNICIPALITY OF HAMILTON-WENTWORTH

DATE SEPT. 6, 1979

BOREHOLE TYPE BOA 3 1/4 I.D. HOLLOW STEM AUGERS, 4" TRICONE

GEOLOGIST _____ A.B.

ELEVATION 655.4

NX CORE

TECHNOLOGIST.

[illegible]

● Piezometer Tip ▲ Standpipe Tip

Gartner Lee Associates Limited

BOREHOLE NO. 2

PROJECT NAME UPPER OTTAWA STREET LANDFILL SITE PROJECT NO. 79-78
CLIENT REGIONAL MUNICIPALITY OF HAMILTON-WENTWORTH DATE SEPT. 16, 17, 21, 1979
BOREHOLE TYPE BOA, 3½" I.D. HOLLOW STEM AUGERS, 3" Tricone GEOLOGIST A.B.
ELEVATION 672.4 TECHNOLOGIST _____

[illegible]

● Piezometer Tip ▲ Standpipe Tip

Gartner Lee Associates Limited

BOREHOLE NO. 3

PROJECT NAME UPPER OTTAWA STREET LANDFILL SITE

PROJECT NO. 79-78

CLIENT REGIONAL MUNICIPALITY OF HAMILTON-WENTWORTH

DATE SEPT. 18, 19, 1979

BOREHOLE TYPE BOA, 3 1/4" I.D. HOLLOW STEM AUGERS, 3" TRICONE

GEOLOGIST A.B.

ELEVATION 676.0

TECHNOLOGIST_____

[illegible]

● Piezometer Tip ▲ Standpipe Tip

Gartner Lee Associates Limited

BOREHOLE NO. 3 (cont'd)

PROJECT NAME UPPER OTTAWA STREET LANDFILL SITE

PROJECT NO. 79-78

CLIENT REGIONAL MUNICIPALITY OF HAMILTON-WENTWORTH

DATE SEPT. 18, 19, 1979

BOREHOLE TYPE BOA, 3 1/4" I.D. HOLLOW STEM AUGERS, 3" TRICONE

GEOLOGIST A.B.

ELEVATION 676.0

TECHNOLOGIST.

[illegible]

● Piezometer Tip ▲ Standpipe Tip

Gartner Lee Associates Limited

BOREHOLE NO. 4

PROJECT NAME UPPER OTTAWA STREET LANDFILL SITE

PROJECT NO. 79-78

CLIENT REGIONAL MUNICIPALITY OF HAMILTON-WENTWORTH

DATE SEPT. 20, 1979

BOREHOLE TYPE BOA, 3 1/4" I.D. HOLLOW STEM AUGERS, 3" TRICONE

GEOLOGIST A.B.ELEVATION 674.2

TECHNOLOGIST

[illegible]

● Piezometer Tip ▲ Standpipe Tip

Gartner Lee Associates Limited

BOREHOLE NO. 4 (cont'd)

PROJECT NAME	UPPER OTTAWA STREET LANDFILL SITE	PROJECT NO.	79-78
CLIENT	REGIONAL MUNICIPALITY OF HAMILTON-WENTWORTH	DATE	SEPT. 20, 1979
BOREHOLE TYPE	BOA, 3 $\frac{1}{4}$ " HOLLOW STEM AUGERS, 3" TRICONE	GEOLOGIST	A.B.
ELEVATION		TECHNOLOGIST	

[illegible]

● Piezometer Tip ▲ Standpipe Tip

Gartner Lee Associates Limited

BOREHOLE NO. 5

PROJECT NAME UPPER OTTAWA STREET LANDFILL SITE

PROJECT NO 79-78

CLIENT REGIONAL MUNICIPALITY OF HAMILTON-WENTWORTH [NX ROCK CORE]

DATE SEPT. 23, 1979

BOREHOLE TYPE BOA, 3 1/4" I.D. HOLLOW STEM AUGERS, 4" TRICONE

GEOLOGIST A.B.

ELEVATION 655.0

TECHNOLOGIST.

DEPTH	STRATIGRAPHY	DESCRIPTION	SAMPLE				GROUND WATER	REMARKS
			TYPE	BLOWS/FT	M/C	%RECOVERY		
0.6		TOPSOIL:						
5.0		TILL: Medium brown clayey silt till, moist						
		LACUSTRINE CLAYEY SILT: Medium brown clayey silt, moist - turning grey and becoming saturated \pm 15'.						
41.0								
43.0		SAND & GRAVEL - Saturated						
		DOLOSTONE Medium grey, fine crystalline, medium to thick bedded dolostone, cherty, minor sphalerite and gypsum shaly in sections						
			NX			100		
			NX			100		
			NX			100		
78.0		Borehole terminated at 78.0' in dolostone.						

● Piezometer Tip ▲ Standpipe Tip

Gartner Lee Associates Limited

BOREHOLE NO. 6

PROJECT NAME UPPER OTTAWA STREET LANDFILL SITE

PROJECT NO. 79-78

CLIENT REGIONAL MUNICIPALITY OF HAMILTON-WENTWORTH

DATE SEPT. 24, 1979

BOREHOLE TYPE BOA, 3 1/4" I.D. HOLLOW STEM AUGERS, NX CORE

GEOLOGIST _____ A.B.

ELEVATION 648.8

TECHNOLOGIST.

DEPTH	STRATIGRAPHY	DESCRIPTION	SAMPLE				GROUND WATER	REMARKS
			TYPE	BLOWS/FT	M/C	%RECOVERY		
0.5		TOPSOIL						
5.0		TILL: Medium brown clayey silt till, moist						
		LACUSTRINE CLAYEY SILT: Medium brown clayey silt becoming grey and saturated at $\pm 15'$.						
49.0								
50.0		SAND AND GRAVEL						
		DOLOSTONE: Medium grey, fine crystalline, medium to thick bedded dolostone, cherty minor sphalerite						
76.0								
		Borehole terminated at 78.0' in dolostone.						

● Piezometer Tip ▲ Standpipe Tip

Gartner Lee Associates Limited

BOREHOLE NO. 7

PROJECT NAME UPPER OTTAWA STREET LANDFILL SITE

PROJECT NO 79-78

CLIENT REGIONAL MUNICIPALITY OF HAMILTON-WENTWORTH

DATE SEPT. 13, 1979

BOREHOLE TYPE BOA, 3 1/4" I.D. HOLLOW STEM AUGERS, NX CORE
4" TRICONE

GEOLOGIST _____ A.B.

ELEVATION 645.6

TECHNOLOGIST

[illegible]

● Piezometer Tip ▲ Standpipe Tip

Gartner Lee Associates Limited

BOREHOLE NO. 8

PROJECT NAME UPPER OTTAWA STREET LANDFILL SITE

PROJECT NO. 79-78

CLIENT REGIONAL MUNICIPALITY OF HAMILTON-WENTWORTH

DATE SEPT. 6, 7, 1979

BOREHOLE TYPE BOA, 3 1/4" I.D. HOLLOW STEM AUGERS, 4" TRICONE NX CORE

GEOLOGIST A.B.

ELEVATION 621.9

TECHNOLOGIST

DEPTH	STRATIGRAPHY	DESCRIPTION	SAMPLE				GROUND WATER	REMARKS
			TYPE	BLOWS / FT	M/C	% RECOVERY		
0.0		TILL: Medium brown clayey silt till, moist - turning grey and wet at ± 15'						
25.5		DOLOSTONE Medium grey, fine crystalline, thin to medium bedded dolostone, cherty - chert ending and dolostone becoming shaly at 65.0' - porous from 61.0'-64.0'	NX			100		4" Tricone to 44.0'
			NX			100		- changing to Gasport Dolomite at 61'
			NX			100		- changing at 65' Decew/Rochester
70.0		Borehole terminated at 70.0' in dolostone.						

● Piezometer Tip ▲ Standpipe Tip

Gartner Lee Associates Limited

BOREHOLE NO. 9

PROJECT NAME UPPER OTTAWA STREET LANDFILL SITE

PROJECT NO. 79-78

CLIENT REGIONAL MUNICIPALITY OF HAMILTON-WENTWORTH

DATE SEPT. 11, 12, 1979

BOREHOLE TYPE BOA 3 1/2" HOLLOW STEM AUGERS, 3" & 4" TRICONES

GEOLOGIST A.B.

ELEVATION 596.2

TECHNOLOGIST_____

DEPTH	STRATIGRAPHY	DESCRIPTION	SAMPLE				GROUND WATER	REMARKS
			TYPE	BLOWS/FT	M/C	%RECOVERY		
0.6		TOPSOIL						
5.0		LACUSTRINE CLAYEY SILT Medium brown clayey silt, moist						
		DOLOSTONE Medium grey dolostone - cherty						Goat Island Dolomite (Ancaster Chert beds)
32.0		Borehole terminated at 32.0' in dolostone.						

● Piezometer Tip ▲ Standpipe Tip

Gartner Lee Associates Limited

BOREHOLE NO. 10

PROJECT NAME UPPER OTTAWA STREET LANDFILL SITE

PROJECT NO 79-78

CLIENT REGIONAL MUNICIPALITY OF HAMILTON-WENTWORTH

DATE Sept. 12, 1979

BOREHOLE TYPE BOA, 3 1/4" I.D. HOLLOW STEM AUGERS, 4" TRICONE NX CORE

GEOLOGIST A.B.ELEVATION 594.3

TECHNOLOGIST.

[illegible]

● Piezometer Tip ▲ Standpipe Tip

Gartner Lee Associates Limited

BOREHOLE NO. 11

PROJECT NAME UPPER OTTAWA STREET LANDFILL SITE

PROJECT NO. 79-78

CLIENT REGIONAL MUNICIPALITY OF HAMILTON-WENTWORTH

DATE March 4, 5, 1980

BOREHOLE TYPE BOA 3 1/4" I.D. AUGERS, 3" & 4" TRICONES

GEOLOGIST A.B.

ELEVATION 600.6

TECHNOLOGIST.



DEPTH	STRATIGRAPHY	DESCRIPTION	SAMPLE				GROUND WATER	REMARKS
			TYPE	BLOWS / FT	M / C	% RECOVERY		
0.6		TOPSOIL						
11.5		LACUSTRINE CLAYEY SILT Medium brown clayey silt, wet; saturated at 3.0' and turning grey at 7.0'						
51.0		DOLOSTONE Medium grey fine crystalline, medium bedded dolostone; cherty to 41.0'; porous from 41.0'-45.7'; becoming shaly dolostone from 45.7'.						
		Borehole terminated at 51.0' in shaly dolostone.						

● Piezometer Tip ▲ Standpipe Tip

Gartner Lee Associates Limited

BOREHOLE NO. G.M. 1

PROJECT NAME UPPER OTTAWA STREET LANDFILL SITE PROJECT NO. 79-78
 CLIENT REGIONAL MUNICIPALITY OF HAMILTON-WENTWORTH DATE Sept. 10, 11, 1979
 BOREHOLE TYPE BOA 3 1/4" I.D. HOLLOW STEM AUGERS, 3" TRICONE GEOLOGIST A.B.
 ELEVATION 614.3 TECHNOLOGIST _____

DEPTH	STRATIGRAPHY	DESCRIPTION	SAMPLE				GROUND WATER	REMARKS
			TYPE	BLOWS/FT	M/C	%RECOVERY		
0.0								
		LACUSTRINE CLAYEY SILT Medium brown lacustrine clayey silt, moist -turning grey 18.0'						
26.0								
		DOLOSTONE Medium grey dolostone -cherty						
38.0								
		Borehole terminated at 38.0' in dolostone						

1/2" Gas monitor installation

BOREHOLE NO. G.M. 3

PROJECT NAME UPPER OTTAWA STREET LANDFILL SITE

PROJECT NO 79-78

CLIENT REGIONAL MUNICIPALITY OF HAMILTON-WENTWORTH

DATE Sept. 11, 1979

BOREHOLE TYPE BOA 3 1/4" I.D. HOLLOW STEM AUGERS, 3" TRICONE

GEOLOGIST A. B.

ELEVATION 636.1

TECHNOLOGIST

[illegible]

● Piezometer Tip ▲ Standpipe Tip

Gartner Lee Associates Limited

BOREHOLE NO. G.M. 4

PROJECT NAME UPPER OTTAWA STREET LANDFILL SITE

PROJECT NO 79-78

CLIENT REGIONAL MUNICIPALITY OF HAMILTON-WENTWORTH

DATE Sept. 13, 1979

BOREHOLE TYPE BOA 3 1/4" I.D. HOLLOW STEM AUGERS, 3" TRICONE

GEOLOGIST A.B.

ELEVATION 632.8

TECHNOLOGIST

[illegible]

● Piezometer Tip ▲ Standpipe Tip

Gartner Lee Associates Limited

BOREHOLE NO. G.M. 5

PROJECT NAME UPPER OTTAWA STREET LANDFILL SITE

PROJECT NO 79-78

CLIENT REGIONAL MUNICIPALITY OF HAMILTON-WENTWORTH

DATE Sept. 13, 1979

BOREHOLE TYPE BOA 3 1/4" I.D. HOLLOW STEM AUGERS, 3" TRICONE

GEOLOGIST A.B.

ELEVATION 645.1

TECHNOLOGIST

[illegible]

● Piezometer Tip ▲ Standpipe Tip

Gartner Lee Associates Limited

BOREHOLE NO. G.M. 6

PROJECT NAME UPPER OTTAWA STREET LANDFILL SITE

PROJECT NO. 79-78

CLIENT REGIONAL MUNICIPALITY OF HAMILTON-WENTWORTH



DATE Sept. 14, 1979

BOREHOLE TYPE BOA 3 1/4" I.D. HOLLOW STEM AUGERS, 3" TRICONE

GEOLOGIST A.B.

ELEVATION 647.5

TECHNOLOGIST.

DEPTH	STRATIGRAPHY	DESCRIPTION	SAMPLE				GROUND WATER	REMARKS
			TYPE	BLOWS / FT	M / C	% RECOVERY		
0.0								
4.0		FILL Medium brown clayey silt, boulders, concrete, moist						
		DOLOSTONE Medium grey dolomite -cherty						
19.0		Borehole terminated at 19.0' in dolostone						1/2" Gas Monitor installation

● Piezometer Tip ▲ Standpipe Tip

Gartner Lee Associates Limited

BOREHOLE NO. G.M. 7

PROJECT NAME UPPER OTTAWA STREET LANDFILL SITE

PROJECT NO. 79-78

CLIENT REGIONAL MUNICIPALITY OF HAMILTON-WENTWORTH

DATE March 4, 1980

BOREHOLE TYPE BOA 3 1/4" I.D. AUGERS, 3" TRICONE

GEOLOGIST A.B.

ELEVATION 648.4

TECHNOLOGIST_

[illegible]

● Piezometer Tip ▲ Standpipe Tip

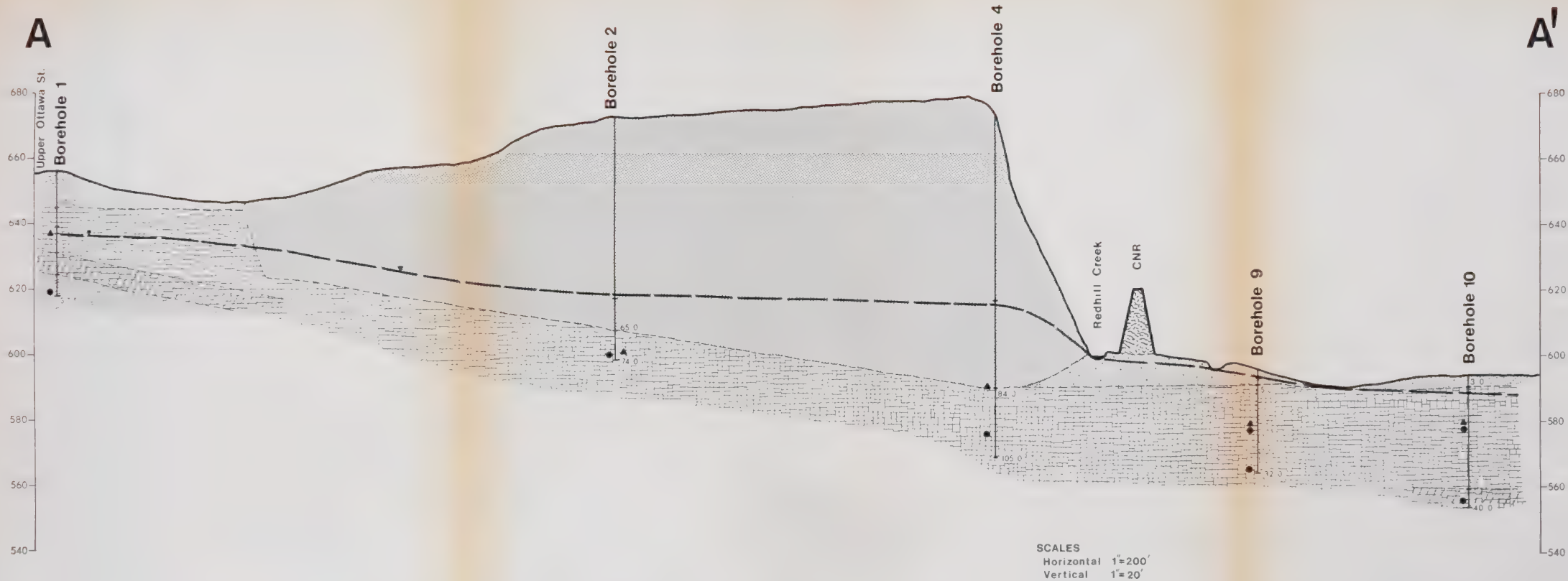
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FIELD TEST RESULTS

FIELD PERMEABILITY TEST RESULTS

BOREHOLE	DEPTH (ft)	PERMEABILITY (cm/sec)		
		Pressure Packer	Slug Test	Formation
6	52.5-57.5	1.7x10 ⁻⁶ - 1.1x10 ⁻⁵ 9.6x10 ⁻⁷ - 1.3x10 ⁻⁵		Goat Island Dolostone (Dolomite)
6	62.5-67.5	1.7x10 ⁻⁶ - 2.1x10 ⁻⁵ 1.7x10 ⁻⁶ - 2.1x10 ⁻⁵		
6	68.5-73.5	1.7x10 ⁻⁶ - 2.7x10 ⁻⁵ 1.8x10 ⁻⁶ - 2.2x10 ⁻⁵		
5	57.5-62.5	1.7x10 ⁻⁶ - 9.4x10 ⁻⁶ 1.4x10 ⁻⁶ - 7.1x10 ⁻⁶		
5	62.5-67.5	2.1x10 ⁻⁶ - 9.4x10 ⁻⁶ 9.6x10 ⁻⁷ - 5.7x10 ⁻⁶		
5	70.5-75.5	1.6x10 ⁻⁶ - 9.4x10 ⁻⁶ 1.2x10 ⁻⁶ - 7.1x10 ⁻⁶		
10	22.5-27.5	1.9x10 ⁻⁶ - 1.2x10 ⁻⁵ 1.3x10 ⁻⁶ - 7.4x10 ⁻⁶		
10	27.5-32.5	1.5x10 ⁻⁶ - 9.6x10 ⁻⁶ 1.9x10 ⁻⁶ - 1.4x10 ⁻⁵		Goat Island Gasport Dolostone
10	32.5-37.5	1.5x10 ⁻⁶ - 9.6x10 ⁻⁵ 9.6x10 ⁻⁷ - 1.1x10 ⁻⁵		

CROSS SECTIONS



LEGEND

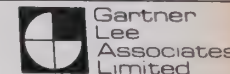
- WASTE
- EARTH FILL
- TILL
- CLAYEY SILT
- DOLOSTONE Goat Island Ancaster Chert Beds
- DOLOSTONE Gasport
- DECEW ROCHESTER FM

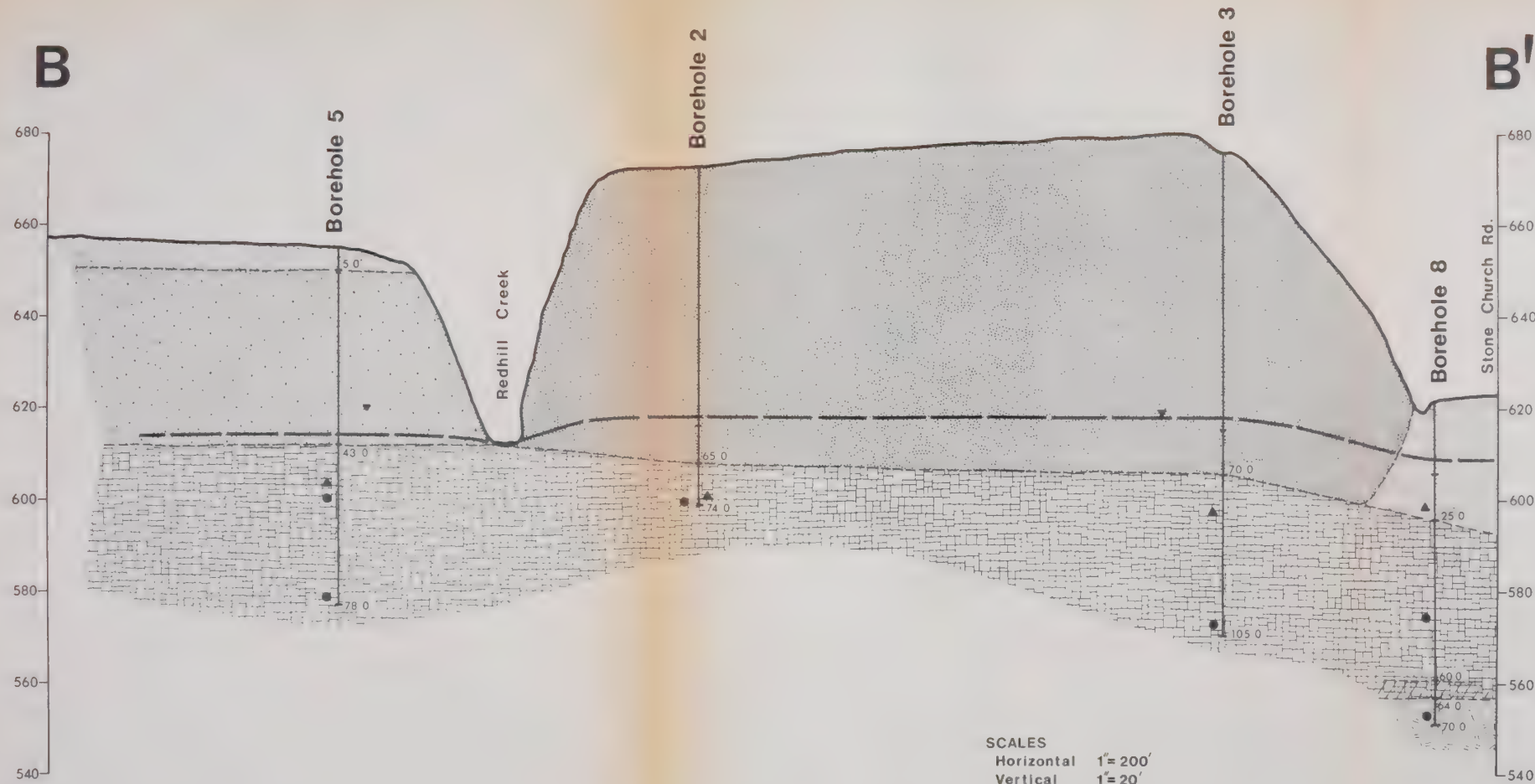
- Assumed Ground Surface
- Stratigraphic Change
- Water Table June 1980
- Standpipe Tip
- Piezometer Tip
- End Of Borehole

Cross Section A-A' 8

Detailed Sub-Surface Leachate
And Gas Migration Study
Upper Ottawa Street Landfill Site
for
Regional Municipality Of
Hamilton - Wentworth

PROJECT 79-78





LEGEND

- WASTE
- TILL
- CLAYEY SILT
- DOLOSTONE Goat Island Ancaster Chert Beas
- DOLOSTONE Gasport
- DECEW ROCHESTER FM

- Assumed Ground Surface
- Stratigraphic Change
- Water Table June 1980
- Standpipe Tip
- Piezometer Tip
- End Of Borehole

Cross-Section B-B' 9

Detailed Sub-Surface Leachate
And Gas Migration Study
Upper Ottawa Street Landfill Site
for
Regional Municipality Of
Hamilton - Wentworth

PROJECT 79-78



SECTION B

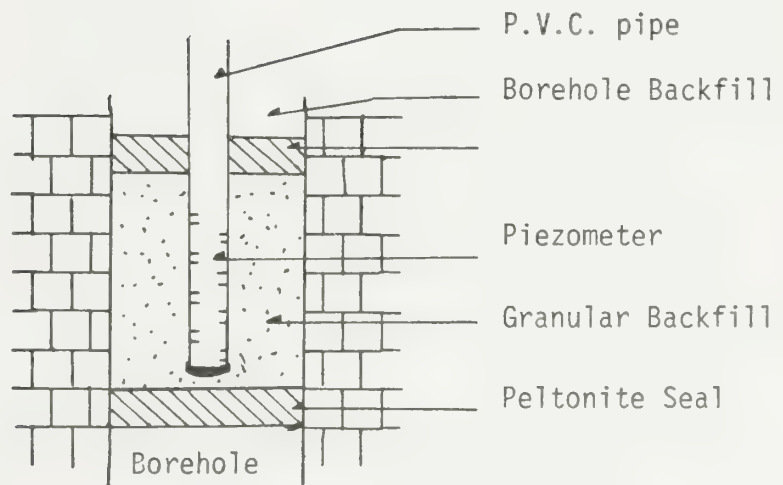
GROUND WATER DETAILS

GROUND WATER MONITOR DETAILS

GROUND WATER MONITOR DETAILS

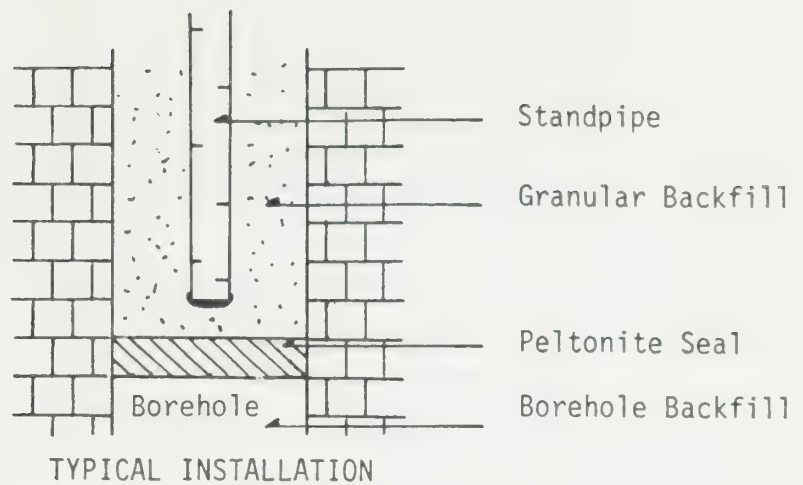
INSTALLATION DETAILS

- A. PIEZOMETER: The piezometer consists of an 18-inch long slotted pipe $1\frac{1}{4}$ inches in diameter. Piezometers are used to measure the hydrostatic pressure, to obtain ground water samples and to measure in situ permeability.

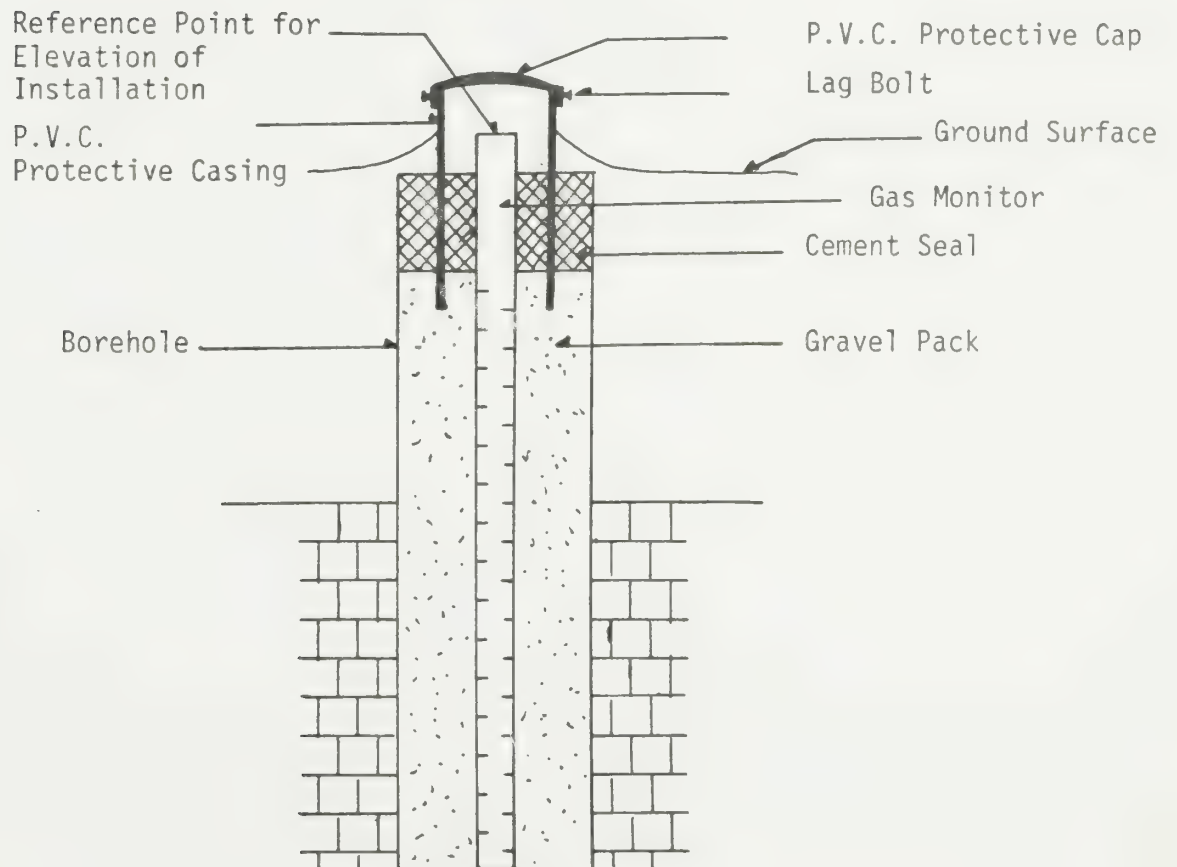


TYPICAL INSTALLATION

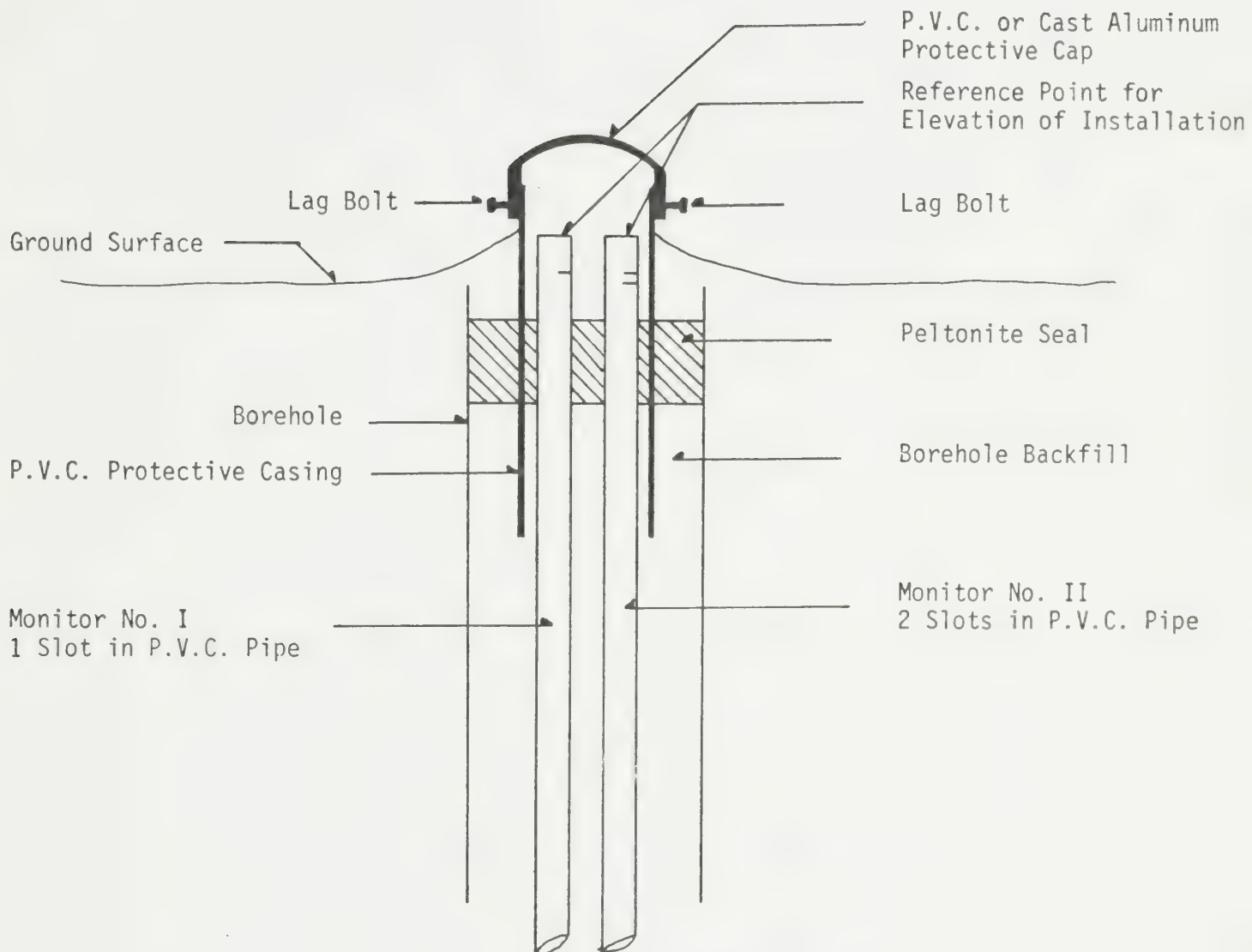
- B. STANDPIPE: Standpipes consist of P.V.C. or C.P.V.C. pipe with the bottom 10 feet of each standpipe slotted every 1.0 foot. Standpipes are used to measure the ground water table and to obtain ground water samples.



- C. GAS MONITOR: Gas monitors are slotted every 4 inches from 2 feet below the surface to the bottom of the pipe. The borehole is back filled with gravel to 2 feet below the ground surface and cement is put on the gravel to act as a seal.



SURFACE DETAILS FOR PIEZOMETERS AND STANDPIPES



Note: All installations have been protected by casing

GROUND WATER MONITOR DETAILS *

Table 2

BOREHOLE NO.	MONITOR				LOCATION OF TIP		LOCATION OF SEAL	
	No.	Diameter (in.)	Type	Elev. (a.s.l.)	Depth (ft.)	Elev. (a.s.l.)	Depth (ft.)	Elev. (a.s.l.)
1	1	1 1/4	●	656.4 (ft.)	37.5	618.9 (ft.)	35.0	621.4 (ft.)
	11	1/2	CPVC ▲	656.4	20.0	636.4	20.0, 9.0, 3.0	636.4, 647.4 653.4
2	1	1 1/4	●	673.4	73.0	600.4	70.0, 3.0	603.4, 670.4
	11	1 1/4	▲	673.9	75.0	598.9	65.0, 2.0	608.9, 671.9
3	1	1 1/4	●	676.4	103.8	572.6	100.3, 1.3	576.1, 675.1
	11	1 1/4	▲	676.9	80.0	596.9	69.0, 2.0	607.9, 674.9
	111	1 1/4	▲	678.5	43.5	635.0	22.5	656.0
	1111	1 1/4	▲	678.5	22.5	656.0	2.5	676.0
4	1	1 1/4	●	675.0	99.8	575.2	93.8, 1.8	581.2, 673.2
	11	1 1/4	▲	675.2	85.5	589.7	75.0, 2.0	600.2, 673.2
5	1	1 1/4	●	657.0	79.0	578.0	75.0	582.0
	11	1/2	●	657.0	58.5	598.5	58.5, 54.0	598.5, 603.0
	111	1/2	▲	657.0	54.0	603.0	43.0, 3.0	614.0, 654.0
6	1	1 1/4	●	650.8	77.0	573.8	74.0	576.8
	11	1/2	●	650.8	67.0	583.8	67.0, 63.0	583.8, 587.8
	111	1/2	▲	650.8	50.0	600.8	50.0, 38.0, 3.0	600.8, 612.8, 647.8
7	1	1 1/4	●	647.1	46.0	601.1	42.5	604.6
	11	1/2	●	647.1	25.5	621.6	25.5, 21.5	621.6, 625.6
	111	1/2	▲	647.1	19.5	627.6	19.5, 8.5, 2.5	627.6, 644.6, 638.6
8	1	1 1/4	●	621.9	69.6	552.3	66.0	555.9
	11	1/2	CPVC ●	621.7	48.3	573.4	48.3, 44.0	573.4, 577.7
	111	1/2	CPVC ▲	621.9	24.2	597.7	24.2, 13.0, 1.0	597.7, 608.9, 620.9
9	1	1 1/4	●	598.2	34.0	564.2	31.0	567.2
	11	1/2	●	598.1	21.9	576.2	21.9, 19.9	576.2, 578.2
	111	1/2	▲	598.1	19.9	578.2	8.9, 2.9	589.2, 595.2
10	1	1 1/4	●	596.4	42.0	555.3	39.0	558.3
	11	1/2	●	596.5	20.0	577.3	20.0, 18.0	577.3, 579.3
	111	1/2		596.5	18.0	579.3	7.0, 4.0	590.3, 593.3
11	1	1 1/4	●	602.6	53.0	549.6	59.0,	543.6
	11	3/4	●	602.6	22.0	580.6	22.0, 17.0	580.6, 585.6
	111	1/2	▲	602.5	10.0	592.5	3.0	599.5
G.M.1	1	1/2	▲	615.8	39.0	576.8	3.5	612.3
G.M.2	1	1/2	▲	622.2	39.0	583.2	2.5	619.7
G.M.3	1	1/2	▲	636.6	24.5	612.1	2.5	634.1
G.M.4	1	1/2	▲	636.6	24.5	612.1	2.5	634.1

● - Piezometer ▲ - Standpipe

Gartner Lee Associates Limited

* All measurements taken from the top of each monitor.

Table 2

● - Piezometer ▲ - Standpipe

GROUND WATER ELEVATIONS

GROUND WATER ELEVATIONS (ft. a.s.l.)

BOREHOLE NUMBER	MONITOR		OCT 10 1979	OCT 31 1979	DEC 3 1979	JAN 7 1980	APR 7 1980	JUNE 13 1980	SEPT. 4 1980			
	No.	Type										
1	I	●	627.5	626.4	626.0	628.0	627.2	626.4	626.3			
	II	▲	634.4	636.4	635.9	639.2	637.8	637.0	638.4			
2	I	●	613.4	613.4	614.4	616.1	616.8	608.4	607.0			
	II	▲	615.9	615.9	615.4	616.9	620.4	617.7	617.7			
3	I	●	603.4	604.1	610.1	611.1	610.9	608.0	destroyed			
	II	▲	615.1	616.9	Destroyed				—			
	III	▲							650.2			
	IIII	▲							658.2			
4	I	●	592.5	591.5	594.2	594.5	596.5	592.4	590.5			
	II	▲	616.7	617.0	615.7	616.7	614.7	615.0	610.0			
5	I	●	595.4	596.9	597.3	600.5	602.3	588.6	597.2			
	II	●	602.0	602.0	602.0	605.0	602.9	603.2	602.3			
	III	▲	605.2	613.0	616.0	618.9	613.0	613.9	612.9			
6	I	●	602.3	602.8	603.1	603.3	603.4	603.7	602.3			
	II	●	602.5	602.3	602.4	604.0	603.3	603.8	602.7			
	III	▲	638.3	635.8	635.3	637.5	637.0	636.7	634.6			

● - Piezometer

▲ - Standpipe

GROUND WATER ELEVATIONS (ft. a.s.l.)

BOREHOLE NUMBER	MONITOR		OCT 10 1979	OCT 31 1979	DEC 3 1979	JAN 7 1980	APR 7 1980	JUNE 13 1980	SEPT 4 1980			
	No.	Type										
7	I	●	606.6	606.8	608.5	608.1	609.1	608.0	608.9			
	II	●	625.1	626.1	627.9	628.0	629.6	628.3	628.1			
	III	▲	628.0	627.0	628.2	628.9	629.9	628.8	628.2			
8	I	●	598.7	600.6	601.9	602.1	603.4	602.5	602.6			
	II	●	598.5	600.9	602.3	604.3	604.2	605.6	603.7			
	III	▲	605.9	607.7	602.9	605.3	604.7	608.9	605.0			
9	I	●	590.7	589.6	591.8	591.7	594.3	592.5	591.2			
	II	●	591.0	590.0	591.9	592.0	594.3	592.5	591.4			
	III	▲	591.4	590.3	592.2	592.1	594.0	592.9	591.6			
10	I	●	586.6	586.4	588.0	587.9	Destroyed	—	—			
	II	●	587.2	587.7	588.5	588.8	Destroyed	—	—			
	III	▲	587.6	588.6	588.6	588.7	Destroyed	—	—			
11	I	●					599.2	595.5	594.7			
	II	●					599.2	596.1	595.7			
	III	▲					599.2	596.2	595.9			

● — Piezometer

▲ — Standpipe

GROUND WATER ELEVATIONS (ft. a.s.l.)

BOREHOLE NUMBER	MONITOR		OCT 10 1979	OCT 31 1979	DEC 3 1979	JAN 7 1980	APR 7 1980	JUNE 13 1980	SEPT 4 1980			
	No.	Type										
G.M. 1	I	▲	598.3	600.5	609.3	606.4	610.5	608.2	604.1			
G.M. 2	I	▲	603.7	607.0	602.7	605.3	609.2	608.8	605.1			
G.M. 3	I	▲	623.9	623.9	621.3	625.3	625.7	624.9	623.9			
G.M. 4	I	▲	630.2	630.4	631.8	631.8	629.2	631.5	632.0			
G.M. 5	I	▲	630.5	630.9	632.3	632.8	634.2	632.6	629.2			
G.M. 6	I	▲	633.7	634.7	637.1	637.2	639.1	636.2	641.6			
G.M. 7	I	▲					639.6	636.6	634.2			

● - Piezometer

▲ - Standpipe

BACKGROUND CHEMISTRY

PROVINCIAL WATER QUALITY OBJECTIVES

INORGANICS AND OTHER PARAMETERS

Conductivity	no objective
pH	6.5 to 8.5
Hardness	no objective
Chloride	250 ppm
Total Kjeldahl	0.15 ppm
Free Ammonia	0.02 ppm
Phenol	1 ppb
Nitrate	10 ppm
BOD	no objective
COD	no objective

HEAVY METALS

Cadmium	0.01 ppm
Chromium	0.05 ppm
Copper	1.0 ppm
Iron	0.3 ppm
Nickel	0.03 ppm
Lead	0.05 ppm
Zinc	5.0 ppm

PROVINCIAL WATER QUALITY OBJECTIVES AND DETECTION LIMITS

PCB AND ORGANOCHLORINE PESTICIDES

	<u>OBJECTIVE</u>	<u>DETECTION LIMIT</u>
PCB	0	.020
HCB		.001
-BHC	.004	.001
LINDANE	.004	.001
B-BHC	.004	.001
HEPTACHLOR	.001	.001
ALDRIN	.001	.001
HEPT. EPOXIDE		.001
THIODAN I		.001
THIODAN II		.001
pp DDE		.001
DIELDRIN	.001	.001
ENDRIN	.002	.001
op DDT	0	.005
pp DDD	0	.005
pp DDT	0	.005
α - CHLORDANE	.007	.001
γ - CHLORDANE	.007	.001
MIREX	0	.005

Note: Objectives and detection limits in ppb

WATER ANALYSIS RESULTS

LOCATION Borehole 1, Installation 1

REMARKS Up-gradient from Landfill

DATE PROPERTY		OCT 31 1979	DEC 3 1979	JAN 7 1980	APR 8, 16 1980						
CONDUCTIVITY μ MHOS/CM.		2400	3200	3300	2700						
pH		7.7	7.35	7.4	7.65						
HARDNESS (Ca CO ₃)		1400	1400	1500	1800						
ALKALINITY (Ca CO ₃)											
CHLORIDES (Cl)		115	24	125	175						
SULPHATES (SO ₄)											
PHOSPHOROUS AS P	Total										
	Soluble										
NITROGEN (N)	Total Kjeldahl	5.0	3.7	12	8						
	Free Ammonia										
	Nitrite										
	Nitrate										
METALS	Potassium (K)										
	Magnesium (Mg)										
	Calcium (Ca)										
	Sodium (Na)										
	Iron (Fe)	11.5	176	250							
	Phenol (ppb)	18	12	16	4						
BOD		10	119	65	174						
COD		290	300	620	68						

NOTE: concentrations in p.p.m. unless otherwise noted.

WATER ANALYSIS RESULTS

LOCATION Borehole 2 Installation 1

REMARKS In Landfill - Below Waste

PROPERTY		DATE	OCT 31 1979	DEC 3 1979	JAN 7 1980	MAY 12 1980							
CONDUCTIVITY μ MHOS CM.					9500								
pH					7.3	7.9							
HARDNESS (Ca CO ₃)					380	358							
ALKALINITY (Ca CO ₃)						9700							
CHLORIDES (Cl)					40	240							
SULPHATES (SO ₄)													
PHOSPHOROUS	Total												
	AS P Soluble												
NITROGEN (N)	Total Kjeldahl				230	1964							
	Free Ammonia												
	Nitrite												
	Nitrate												
METALS	Potassium (K)												
	Magnesium (Mg)												
	Calcium (Ca)												
	Sodium (Na)												
	Iron (Fe)				270								
	Phenol (ppb)				68	.36							
BOD					220	75							
COD					1650	2279							

NOTE: concentrations in p.p.m. unless otherwise noted.

WATER ANALYSIS RESULTS

LOCATION Borehole 4 Installation 1 REMARKS Under Waste

PROPERTY \ DATE		OCT 31 1979	DEC 3 1979	JAN 7 1980	MAY 12 1980					
CONDUCTIVITY μ MHOS/CM.			14,000							
pH			7.90		7.8					
HARDNESS (Ca CO ₃)			490		743					
ALKALINITY (Ca CO ₃)					434					
CHLORIDES (Cl)			880		1755					
SULPHATES (SO ₄)										
PHOSPHOROUS	Total									
	AS P Soluble									
NITROGEN (N)	Total Kjeldahl		210	NOT TESTED	120					
	Free Ammonia									
	Nitrite									
	Nitrate									
METALS	Potassium (K)									
	Magnesium (Mg)									
	Calcium (Ca)									
	Sodium (Na)									
	Iron (Fe)		430							
	Phenol (ppb)		96		170					
BOD			159		175					
COD			1170		632					

NOTE: concentrations in p.p.m. unless otherwise noted.

WATER ANALYSIS RESULTS

LOCATION Borehole 4 Installation II

REMARKS Leachate

PROPERTY		DATE	OCT 31 1979	DEC 3 1979	JAN 7 1980															
CONDUCTIVITY μ MHOS/CM.				2100																
pH				7.20																
HARDNESS (Ca CO ₃)				1330																
ALKALINITY (Ca CO ₃)																				
CHLORIDES (Cl)				58																
SULPHATES (SO ₄)																				
PHOSPHOROUS	Total																			
	AS P Soluble																			
NITROGEN (N)	Total Kjeldahl			44																
	Free Ammonia																			
	Nitrite																			
	Nitrate																			
METALS	Potassium (K)																			
	Magnesium (Mg)																			
	Calcium (Ca)																			
	Sodium (Na)																			
	Iron (Fe)			88																
Phenol (ppb)				180																
BOD				164																
COD				3529																

NOTE: concentrations in p.p.m. unless otherwise noted.

WATER ANALYSIS RESULTS

LOCATION

REMARKS

[illegible]

WATER ANALYSIS RESULTS

LOCATION Borehole 7, Installation I

REMARKS

[illegible]

WATER ANALYSIS RESULTS

LOCATION Borehole 9 Installation 1 REMARKS Down-gradient from Landfill

PROPERTY	DATE		OCT 31 1979	DEC 3 1979	JAN 7 1980	APR 8, 16 1980						
	CONDUCTIVITY μ MHOS/CM.		6500	7000		6000						
pH			7.0	7.10		7.4						
HARDNESS (Ca CO ₃)			1700	2780		2100						
ALKALINITY (Ca CO ₃)												
CHLORIDES (Cl)			1580	45		1305						
SULPHATES (SO ₄)												
PHOSPHOROUS AS P	Total											
	Soluble											
NITROGEN (N)	Total Kjeldahl		93	92.5		177						
	Free Ammonia											
	Nitrite											
	Nitrate											
METALS	Potassium (K)											
	Magnesium (Mg)											
	Calcium (Ca)											
	Sodium (Na)											
	Iron (Fe)		18	3								
	Phenol (ppb)		12	70		4						
	BOD		10	63		154						
	COD		470	325		500						

NOTE: concentrations in p.p.m. unless otherwise noted.

WATER ANALYSIS RESULTS

LOCATION Borehole 9 Installation II

REMARKS Down-gradient from Landfill

DATE		OCT 31 1979	DEC 1979	JAN 7 1980	APR 8,16 1980					
PROPERTY										
CONDUCTIVITY μ MHOS/CM.				8,000	6,000					
pH				6.8	7.0					
HARDNESS (Ca CO ₃)				1650	2540					
ALKALINITY (Ca CO ₃)				1700	1750					
CHLORIDES (Cl)										
SULPHATES (SO ₄)										
PHOSPHOROUS AS P	Total	TESTED	TESTED							
	Soluble	TESTED	TESTED							
NITROGEN (N)	Total Kjeldahl			12.5	170					
	Free Ammonia	NOT	NOT							
	Nitrite	N	N							
	Nitrate									
METALS	Potassium (K)									
	Magnesium (Mg)									
	Calcium (Ca)									
	Sodium (Na)									
	Iron (Fe)			12						
	Phenol (ppb)			12	4					
BOD				32	794					
COD				550	618					

NOTE: concentrations in p.p.m. unless otherwise noted.

WATER ANALYSIS RESULTS

LOCATION Borehole 11, Installation 1

REMARKS Down-gradient

DATE		OCT 31 1979	DEC 3 1979	JAN 7 1980	APR 8, 16 1980						
PROPERTY											
CONDUCTIVITY μ MHOS/CM.						315					
pH						7.6					
HARDNESS (Ca CO ₃)						4300					
ALKALINITY (Ca CO ₃)											
CHLORIDES (Cl)						110					
SULPHATES (SO ₄)											
PHOSPHOROUS	Total										
	AS P Soluble										
NITROGEN (N)	Total Kjeldahl					9.2					
	Free Ammonia										
	Nitrite										
	Nitrate										
METALS	Potassium (K)										
	Magnesium (Mg)										
	Calcium (Ca)										
	Sodium (Na)										
	Iron (Fe)										
	Phenol (ppb)					4					
	BOD					24					
	COD					200					

NOTE: concentrations in p.p.m. unless otherwise noted.

TABLE 5A
GROUND WATER ANALYSIS RESULTS
(APRIL, MAY 1980)

LOCATION PARAMETER PPM	B.H. 1 PIEZ.I	B.H. 2 S.P. II	B.H. 6 PIEZ.I	B.H. 7 PIEZ.I	B.H. 8 PIEZ.I	B.H. 9 PIEZ.I	B.H. 9 PIEZ.II	B.H. 11 PIEZ.I
B.O.D.	220	(130)	86	58	22	40	48	(14)
TOTAL SOLIDS	4,340	16,200	26,400	5,690	15,800	6,970	6,860	9,920
SUSP. SOLIDS	405	7,420	17,700	520	420	95	45	150
CONDUCTIVITY	4,100	25,400	11,000	6,650	20,500	9,400	9,300	13,300
TURBIDITY	165	I	>1,000	225	130	130	150	70
FREE AMMONIA	4.5	2,750	3.2	2.2	7.0	150	140	1.8
TOTAL KJELDHAL	5.0	2,900	10	3.2	7.6	152	1.42	12
NITRITE	0.03	0.20	0.02	0.01	0.01	0.01	0.01	0.01
NITRATE	0.1	0.5	0.1	0.1	0.1	0.1	0.1	0.1
TOTAL PHOSPHOROUS	0.54	19	8.8	0.44	0.18	0.20	0.10	0.10
SOLUBLE PHOSPHOROUS	0.14	8.9	<0.02	0.10	<0.02	0.02	<0.02	<0.02
CHLORIDE	122	2,860	3,350	1,470	7,590	1,590	1,560	2,320
ALKALINITY	266	11,500	2,430	331	201	1,500	1,490	157
pH	7.5	7.6	7.0	7.0	6.7	6.7	6.8	7.2
TOTAL IRON	8.8	190	470	10.4	9.2	2.4	1.2	4.0
C.O.D.	190	4,000	490	160	37	400	410	270

NOTE: I = interference

() = possible interference

Analyses completed by The Ministry of the Environment Laboratory.

WATER ANALYSIS RESULTS

LOCATION Borehole 11 Installation II

REMARKS Down-gradient

PROPERTY		DATE	OCT 31 1979	DEC 3 1979	JAN 7 1980	APR 8, 16 1980				
CONDUCTIVITY μ MHOS/CM.						3200				
pH						7.5				
HARDNESS (Ca CO ₃)						1600				
ALKALINITY (Ca CO ₃)										
CHLORIDES (Cl)						1100				
SULPHATES (SO ₄)										
PHOSPHOROUS AS P	Total		T E S T E D	T E S T E D	T E S T E D					
	Soluble		T E S T E D	T E S T E D	T E S T E D					
NITROGEN (N)	Total Kjeldahl		T E S T E D	T E S T E D	T E S T E D	45.4				
	Free Ammonia		N O T	N O T	N O T					
	Nitrite		N O T	N O T						
	Nitrate									
METALS	Potassium (K)									
	Magnesium (Mg)									
	Calcium (Ca)									
	Sodium (Na)									
	Iron (Fe)									
	Phenol (ppb)					12				
BOD						7				
COD						515				

NOTE: concentrations in p.p.m. unless otherwise noted.

GROUND WATER CONDUCTIVITIES

BOREHOLE NUMBER	MONITOR		Dec. 3 1979	Sept. 4 1980						
	No.	Type								
1	I	●	4000	6000						
	II	▲								
2	I	●	>10,000							
	II	▲	10,000	>10,000						
	III									
	IIII									
	I	●	1,000							
3	II	▲								
4	I	●	3,800							
	II	▲								
5	I	●	820	>10,000						
	II	●								
	III	▲								
6	I	●	6,000	>10,000						
	II	●								
	III	▲		900						
7	I	●	6,000	10,000						
	II	●		900						
	III	▲		1,400						

● — Piezometer

▲ — Standpipe

GROUND WATER CONDUCTIVITIES

BOREHOLE NUMBER	MONITOR		Dec. 3 1979	Sept. 4 1980															
	No.	Type																	
8	I	●	2,000	>10,000															
	II	●																	
	III	▲																	
9	I	●	8,000	>10,000															
	II	●																	
	III	▲																	
10	I	●	4,200																
	II	●																	
11	III	▲		>10,000															
	I	●																	
	II	▲																	
	III	▲																	
	III	▲																	
G.M. 1	I	▲		>10,000															
G.M. 2	I	▲		3,500															
G.M. 3	I	▲		7,000															
G.M. 4	I	▲		>10,000															
G.M. 5	I	▲		2,400															
G.M. 6	I	▲		4,000															
G.M. 7	I	▲		2,500															
	I	▲		5,000															
	I	▲		2,500															
	I	▲		10,000															

● — Piezometer

▲ — Standpipe

TABLE 7
GROUND WATER ANALYSIS RESULTS
METALS (APRIL, MAY 1980)

PARAMETER PPM LOCATION	CADMIUM CD	CHROMIUM CR	COPPER CU	IRON FE	NICKEL NI	LEAD PB	ZINC ZN
BH 1, I	<0.02	ND	0.5	0.2	0.05	0.10	0.05
BH 2, I	<0.01	ND	1.0	-	1.0	0.3	1.2
BH 2, II	<0.02	0.10	2.0	21.0	0.45	0.5	2.5
BH 4, I	<0.01	ND	0.4	-	0.45	0.2	0.6
BH 6, I	<0.02	0.02	1.0	0.6	0.10	0.25	0.05
BH 7, I	<0.02	ND	0.05	0.20	0.05	0.15	0.05
BH 8, I	<0.02	ND	0.7	1.30	0.05	0.15	0.05
BH 9, I	<0.02	0.02	0.9	0.90	0.10	0.10	0.05
BH 9, II	<0.02	0.02	0.8	0.70	0.08	0.20	0.05
BH 11, I	<0.02	0.04	<0.2	0.95	<0.05	<0.05	0.05
BH 11, II	<0.02	0.04	0.3	0.3	<0.05	0.10	0.05

Note: ND = non detected

TABLE 7A
GROUND WATER ANALYSIS RESULTS
METALS (APRIL, MAY 1980)

PARAMETER PPM LOCATION	CADMIUM CD	CHROMIUM CR	COPPER CU	NICKEL NI	LEAD PB	ZINC ZN	ALUMINUM AL	ARSENIC AS
B.H. 6 I	<.005	<.02	0.05	0.02	<.03	0.03	0.62	0.002
B.H. 9, I	<.005	<.02	0.04	0.04	<.03	0.03	1.3	0.004
B.H. 9, II	<.005	<.02	0.05	0.03	<.03	<.01	0.55	0.002
B.H. 11, I	<.005	<.02	0.04	0.02	<.03	0.11	4.4	0.002
B.H. 8, I	<.005	0.04	0.04	0.03	<.03	0.08	4.8	0.002
B.H. 7, I	<.005	0.16	0.14	0.11	0.72	2.1	6.1	0.016
All analyses completed by The Ministry of the Environment Laboratory.								

TABLE 8

GROUND WATER ANALYSIS RESULTS
PCB & ORGANOCHLORINE PESTICIDES (APRIL, MAY, 1980)




PARAMETER PPB	LOCATION	B.H. 1 Piez I	B.H. 2 Piez. I	B.H. 5 Piez. I	B.H. 8 Piez. I	B.H. 9 Piez. I	B.H. 9 Piez II	B.H. 11 Piez. I
PCB		ND	ND	ND	ND	ND	ND	ND
HCB		NT	NT	NT	NT	ND	NT	ND
α - BHC		NT	NT	NT	NT	0.008	NT	0.020
LINDANE		NT	NT	NT	NT	ND	NT	0.001
β - BHC		NT	NT	NT	NT	ND	NT	0.002
HEPTACHLOR		NT	NT	NT	NT	ND	NT	ND
ALDRIN		NT	NT	NT	NT	ND	NT	ND
HEPT. EPOXIDE		NT	NT	NT	NT	NT	NT	NT
THIODAN I		NT	NT	NT	NT	ND	NT	ND
THIODAN II		NT	NT	NT	NT	ND	NT	ND
PP DDE		NT	NT	NT	NT	ND	NT	ND
DIELDRIN		NT	NT	NT	NT	0.030	NT	0.030
ENDRIN		NT	NT	NT	NT	0.007	NT	0.008
OP DDT		NT	NT	NT	NT	ND	NT	ND
PP DDD		NT	NT	NT	NT	ND	NT	ND
PP DDT		NT	NT	NT	NT	ND	NT	ND
α - CHLORDANE		NT	NT	NT	NT	ND	NT	ND
α - CHLORDANE		NT	NT	NT	NT	ND	NT	0.002
γ - MIREX		NT	NT	NT	NT	ND	NT	ND

Note: ND = not detected
NT = not tested

SECTION C

SURFACE WATER DETAILS

Legend

-  Stream Channel
-  Sewered
-  Landfill Site

NOTE = Watershed boundary may vary from that shown through urban area

Hydrologic Setting

7

Detailed Sub-Surface Leachate
And Gas Migration Study
Upper Ottawa Street Landfill Site
for

Regional Municipality Of
Hamilton-Wentworth

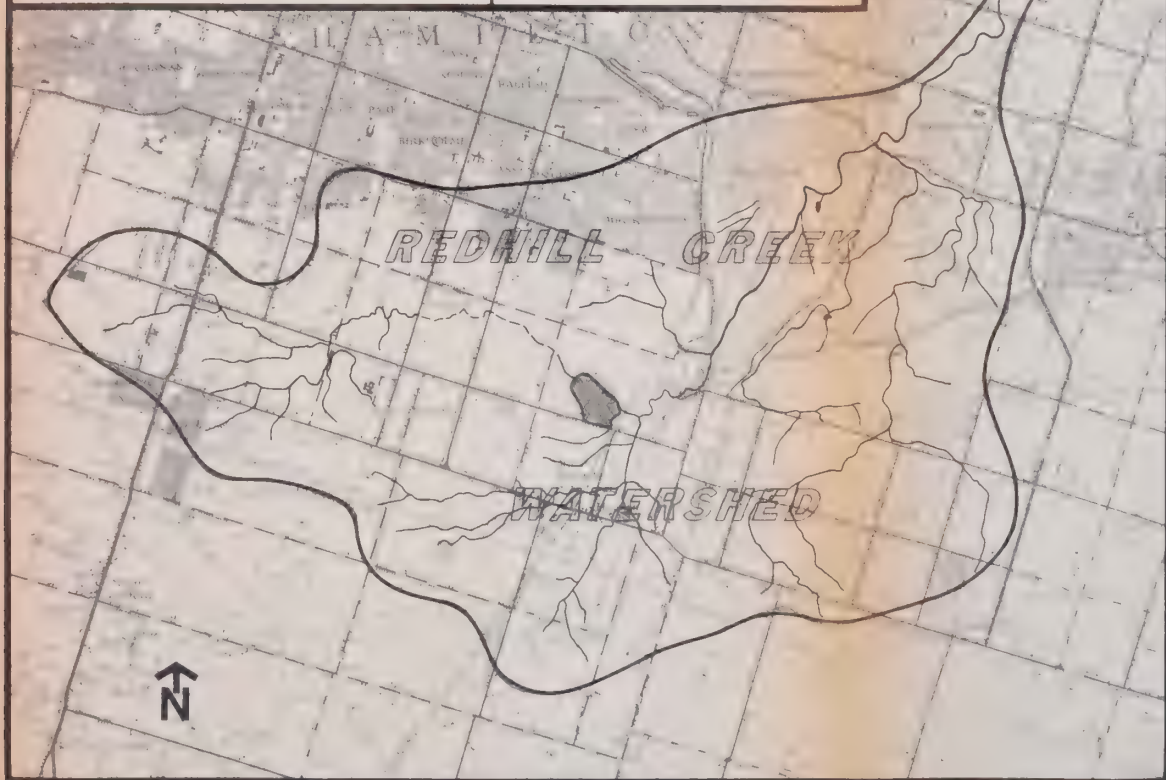
PROJECT 79 78

SCALE 1:50,000

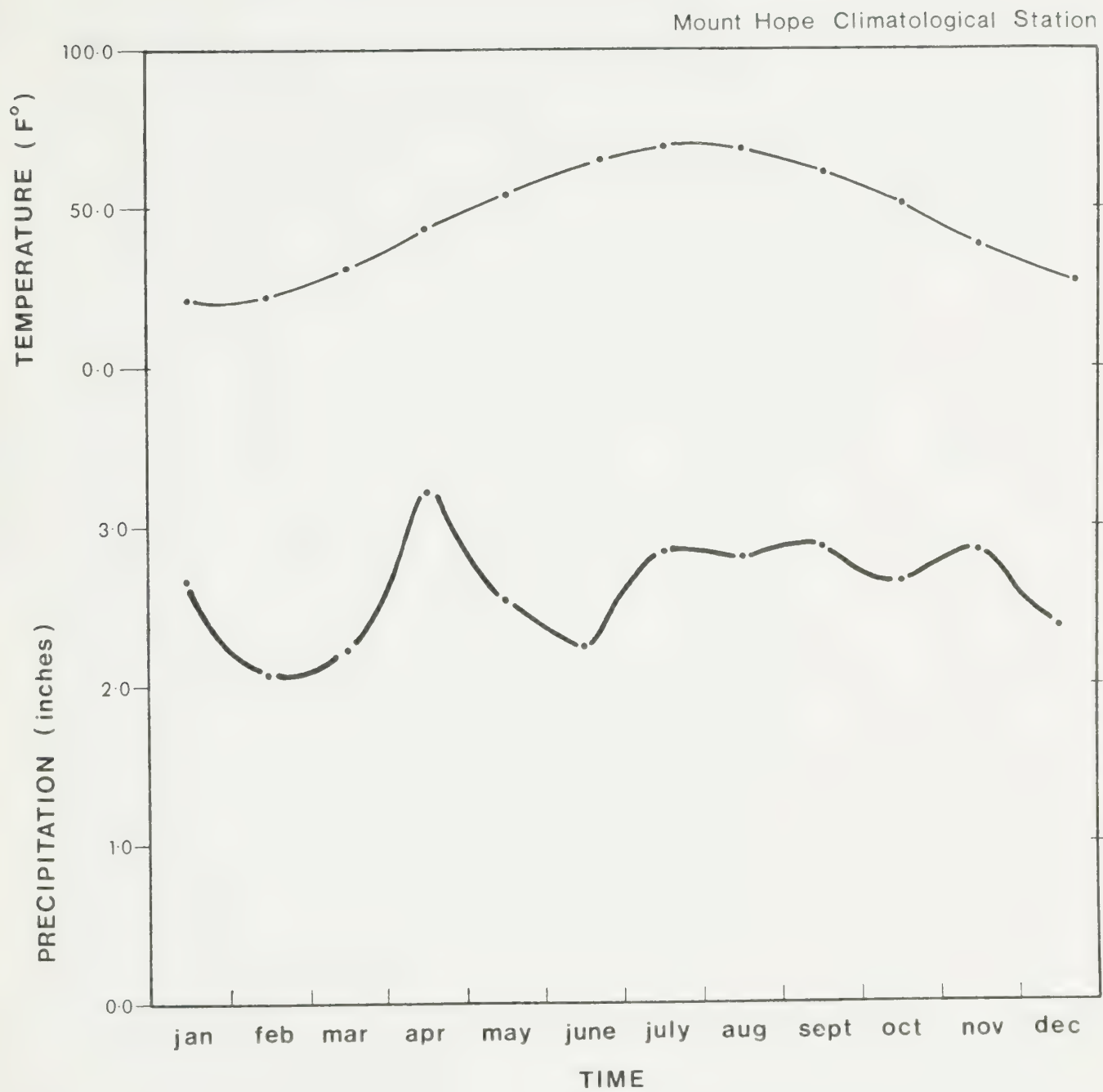


Scale
1:50,000
1 inch = 1.25 miles

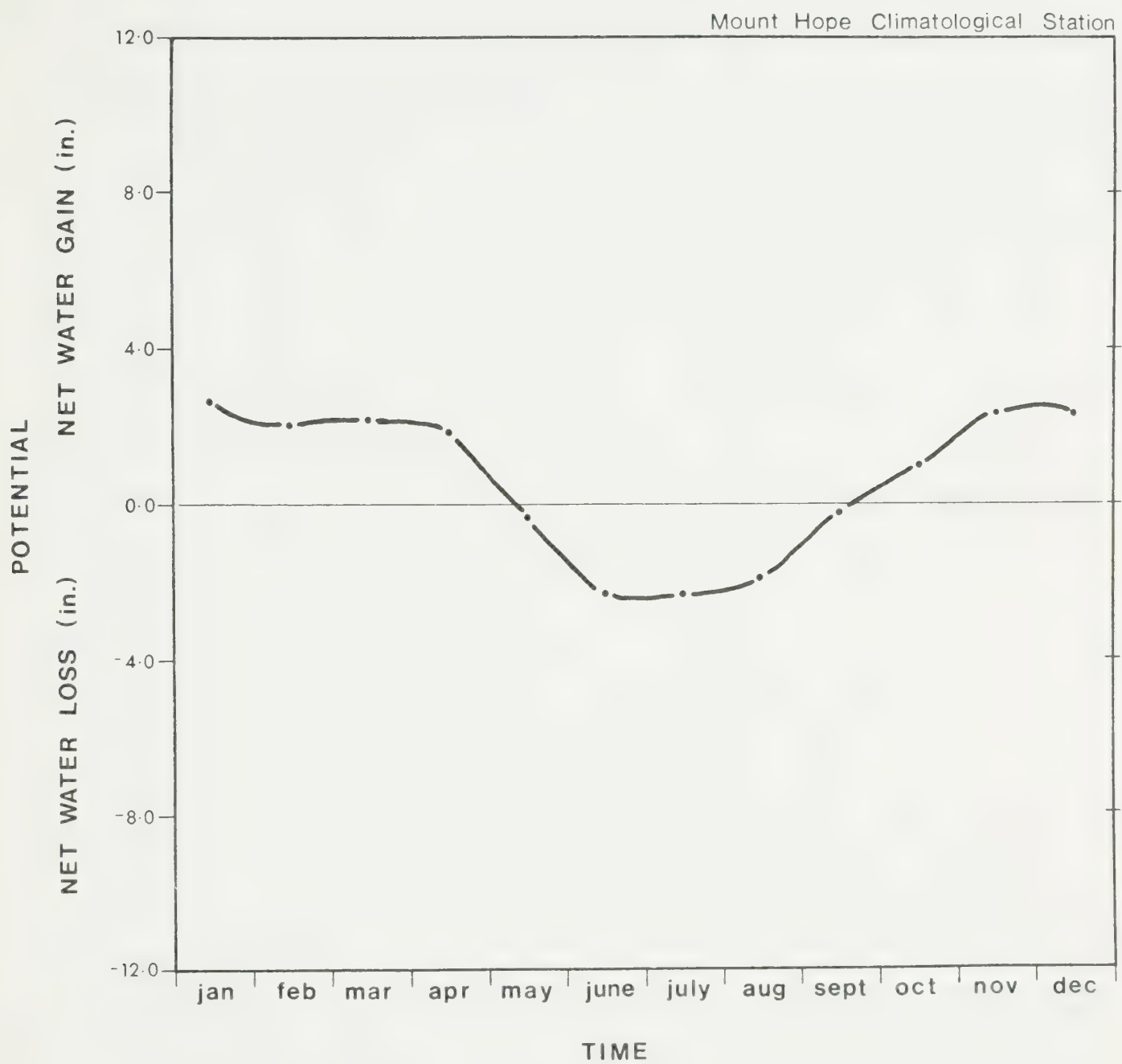
Lake
Ontario



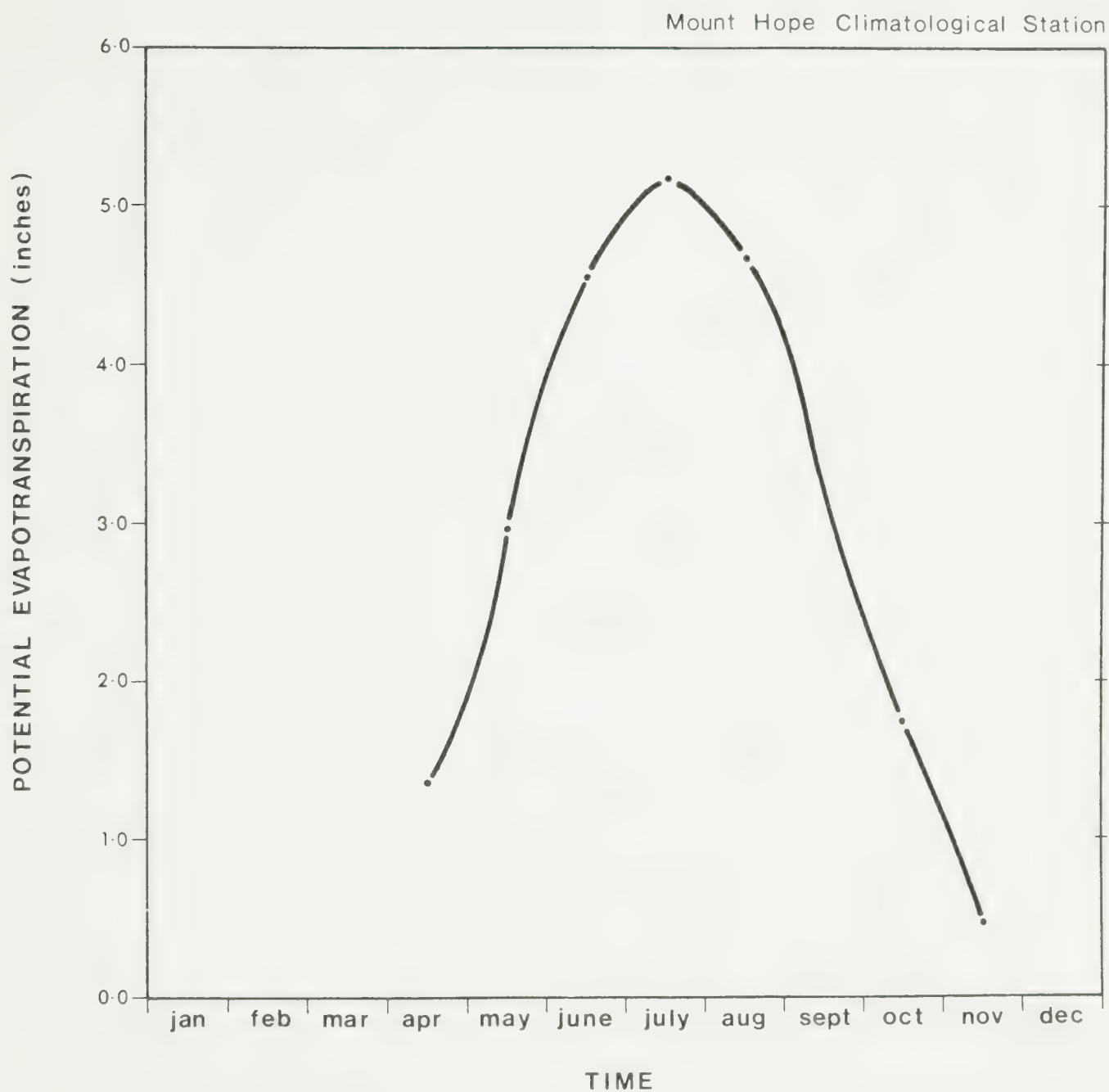
TEMPERATURE · PRECIPITATION GRAPH 8 YEAR NORMALS



WATER BUDGET · 8 YEAR NORMALS



POTENTIAL EVAPOTRANSPIRATION 8 YEAR NORMALS



TEMPERATURE · PRECIPITATION GRAPH 1979-1980

Figure 13

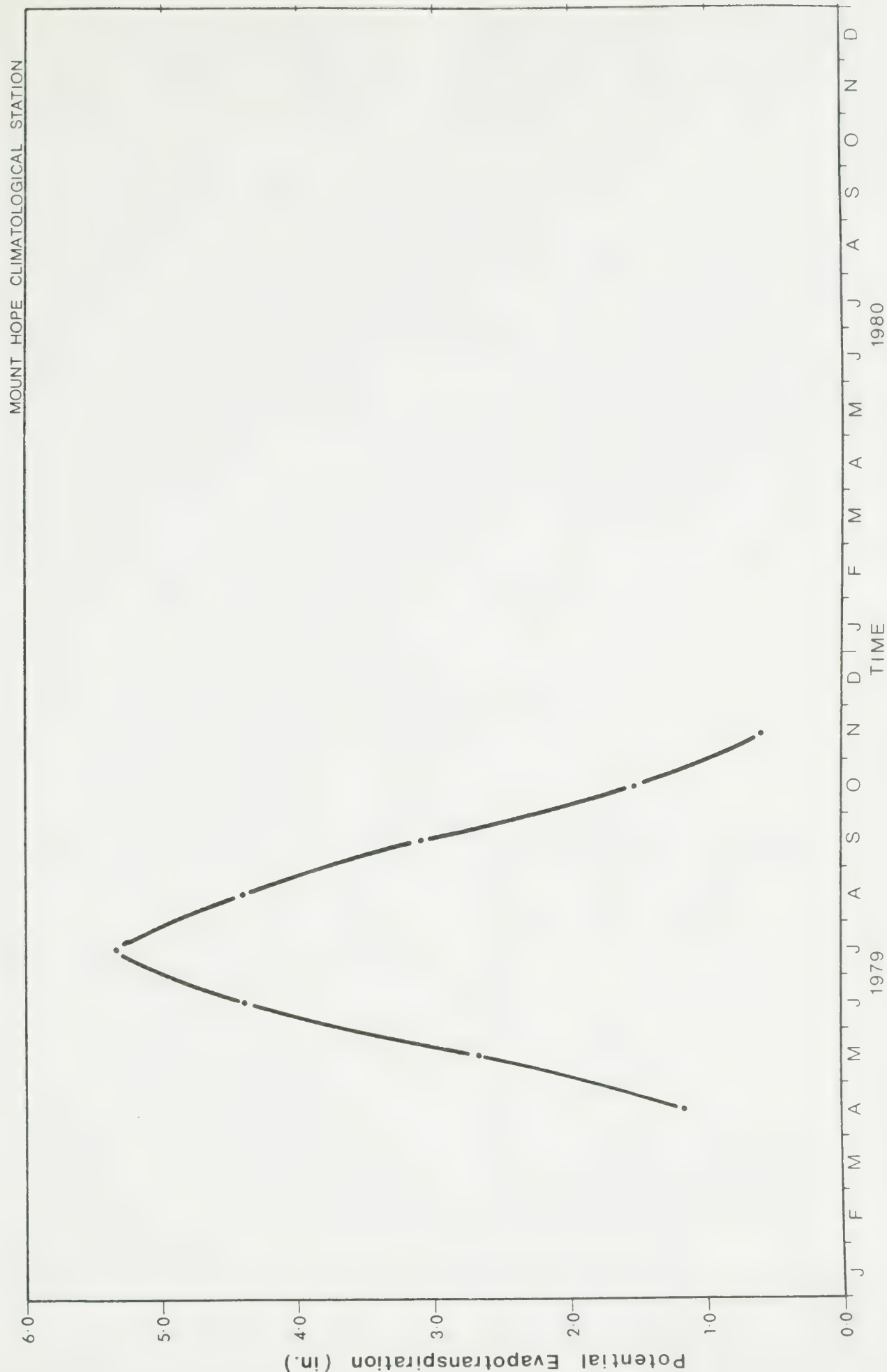


Figure 14

WATER BUDGET 1979-1980



POTENTIAL EVAPOTRANSPIRATION 1979 · 1980





Legend

●
SW 4 Surface Water Monitoring Station

SURFACE WATER STATIONS

6

Proposed Hydrogeological Investigation
Ottawa Street Landfill
for
Regional Municipality of
Hamilton Wentworth

1 mile

Project 79-78

Scale 1:25,000



TABLE 10
SURFACE WATER ANALYSIS RESULTS
OCTOBER 31, 1979

LOCATION PARAMETER PPM	SW 1	SW 2	SW 3	SW 4	SW 5	LEACHATE SITE A	
CONDUCTIVITY (UMHOS/CM)	1000	950	800	700	950	13,000	
PH	7.8	8.1	8.2	7.7	7.7	7.9	
TOTAL HARDNESS	560	500	490	490	640	1700	
CHLORIDE	150	150	115	85	135	3600	
NITRATE	1.20	1.84	1.18	0.52	0.04	-	
AMMONIA	11.0	14.0	8.0	0.12	0.04	330	
TOTAL KJELDAHL	14.2	20.8	11.0	2.1	2.5	535	
BOD	0	3	0	0	0	50	
COD	29	22	7	7	7	1764	
IRON	0.3	0.2	0.1	0.1	0.2	3.3	
PHENOL (PPB)	3	4	1	1	1	84	

Note: Analyses completed by Regional Municipality of Hamilton-Wentworth Laboratory

* Site A is the Leachate pond between the landfill and the railroad embankment by Redhill Creek.

TABLE 11
SURFACE WATER ANALYSIS RESULTS
APRIL 8, 1980

LOCATION PARAMETER PPM	SW 1	SW 2	SW 3	SW 4	SW 5	SW 6	SW 7
CONDUCTIVITY (UMHOS/CM)	720	700	700	720	550	700	700
PH	8.10	8.20	8.10	8.00	8.15	8.15	8.00
TOTAL HARDNESS	388	332	310	282	316	284	310
CHLORIDE	105	127	122	157	73	106	131
AMMONIA	0.75	1.45	1.10	0.10	<0.02	0.60	<0.02
TOTAL KJELDAHL	1.74	2.70	2.40	1.40	0.70	1.70	1.20
BOD	1.1	2.9	2.4	2.1	1.1	1.1	0.9
COD	22	15	18	16	7	41	26
PHENOL (PPB)	0	2.0	0	0	2.0	0	0
IRON	0.30	0.70	0.50	0.85	0.15	0.30	0.25
CADMIUM	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
CHROMIUM	ND	ND	ND	ND	ND	ND	ND
COPPER	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
NICKEL	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
LEAD	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
ZINC	<0.05	<0.05	<0.42	<1.40	<0.60	<0.50	<0.60

Note: ND = not detected

Analyses completed by Regional Municipality of Hamilton-Wentworth Laboratory

TABLE 11A
SURFACE WATER ANALYSIS RESULTS
APRIL, MAY 1980

LOCATION PARAMETER PPM	SW 1	SW 2	SW 3	SW 4	SW 5	SW 6	SW 7
B.O.D.	2.0	2.0	1.6	1.4	0.6	2.0	0.6
TOTAL SOLIDS	845	910	920	980	675	785	665
SUSP. SOLIDS	45	45	45	95	20	30	<15
CONDUCTIVITY	1,050	1,250	1,220	1,330	880	1,100	1,040
TURBIDITY	30	32	2.8	28	52	13	17
FREE AMMONIA	0.7	1.4	1.0	<.1	<.1	0.5	<.1
TOTAL KJELDAHL	1.0	1.5	1.2	0.6	0.4	0.8	0.4
NITRITE	0.06	0.08	0.08	0.08	0.03	0.08	0.02
NITRATE	2.0	1.8	1.7	1.7	2.0	2.0	0.8
TOTAL PHOSPHOROUS	0.06	0.06	0.06	0.10	0.04	0.04	0.02
SOLUBLE PHOSPHOROUS	<.02	0.02	0.02	0.02	<.02	<.02	<.02
CHLORIDE	113	136	133	163	76	113	143
ALKALINITY	183	215	209	210	156	185	196
pH	8.3	8.2	8.1	8.0	8.4	8.2	7.7
TOTAL IRON	1.2	1.4	1.4	2.9	0.70	1.0	0.25
C.O.D.	31	31	31	<20	23	23	27

Analyses completed by The Ministry of the Environment Laboratory.

TABLE 11A
SURFACE WATER ANALYSIS RESULTS
METALS (APRIL, MAY 1980)

LOCATION PARAMETER PPM	SW 1	SW 2	SW 3	SW 4	SW 5	SW 6	SW 7
CADMIUM CA	<.005	<.005	<.005	<.005	<.005	<.005	<.005
CHROMIUM CR	<.02	<.02	<.02	<.02	<.02	<.02	<.02
COPPER CU	<.01	<.01	<.01	0.01	<.01	<.01	<.01
NICKEL NI	<.02	<.02	<.02	0.02	<.02	<.02	<.02
LEAD PB	<.03	<.03	<.03	<.03	<.03	<.03	<.03
ZINC ZN	0.03	0.06	0.07	0.11	<.01	<.04	<.01
ALUMINUM AL	0.93	1.1	1.2	2.0	0.73	0.83	0.06
ARSENIC AS	0.002	0.001	0.002	0.002	0.002	<.001	<.001

Analyses completed by The Ministry of the Environment Laboratory.

Table 12: Types and numbers/Ft² of benthic organisms collected from Redhill Creek in the vicinity of the Ottawa Street Landfill, October 31st, 1979

S T A T I O N					
ORGANISM	1	2	3	4	5
ALDERFLIES <u>Sialis</u>					1
MAYFLIES <u>Callibaetis</u>		1			
CADDISFLIES <u>Cheumatopsyche</u>	33				
<u>Hydropsyche</u>	22		8		
DRAGONFLIES <u>Somatochlora</u>		1			
BEETLES <u>Agabus</u>		8	4		2
<u>Berosus</u>	1				
TRUEFLIES Chironomidae		2		2	4
Dolichopodidae				2	
Empididae	1	2	29	2	
HYDRACARINA (unident.)		1			
AMPHIPODS <u>Hyalloa azteca</u>	279	2	1		1
ISOPODS <u>Asellus</u>	460		2		
SNAILS <u>Lymnaea</u>		9		1	
<u>Physa</u>	2		1	8	1
<u>Valvata sincera</u>		2		1	
CLAMS <u>Pisidium</u>					1
<u>Sphaerium</u>					1

S T A T I O N

ORGANISM	1	2	3	4	5
LEECHES					
Erpobdellidae		2	9		1
Helobdella					
<u>stagnalis</u>	1	7		1	
Hirudinidae		1			
SLUDGEWORMS					
Limnodrilus					
<u>hoffmeisteri</u>		98		75	
<u>L. udekemianus</u>		39			
<u>L. (immature)</u>		78		75	8
<u>Tubifex tubifex</u>		58		30	2
<u>T. (immature)</u>		352		226	14
EARTHWORMS					
(unident.)		4		2	
TOTAL NO. TAXA	8	16	7	10	10
TOTAL NO. ORGS. PER Ft ²	799	663	54	425	36

TABLE 13
SEDIMENT ANALYSIS RESULTS¹

	<u>LOSS ON IGNITION (%)</u>	<u>PHENOL (ppb)</u>	<u>IRON² (%)</u>	<u>PCB³ (ppm)</u>
SW2 (downstream)	4.8	10	2.88	244
SW4 (upstream)	4.2	10	1.44	662

M.O.E. SEDIMENT ANALYSES

<u>LOCATION-DATE</u>	<u>PCB CONCENTRATION</u>
Redhill Creek at Upper Ottawa Street October 25, 1979	140 ppb
Redhill Creek near SW1 October 25, 1975	70 ppb
Discharge channel from City Works Yard at Redhill Creek, March 24, 1980	200 ppb
Redhill Creek at storm sewer outlet (near SW4) March 24, 1980	60 ppb
Around Oil Storage Tank in City Works Yard	900 ppb

Notes: 1. Samples taken October 31, 1979
 2. Iron results are total iron
 3. Lab analysis by Peninsula Chemical Analysis

SECTION D

COMBUSTIBLE GAS

TABLE 9
COMBUSTIBLE GAS RESULTS

DATE TESTED LOCATION	OCTOBER 10, 1979	DECEMBER 3, 1979	JANUARY 8, 1980	APRIL 7, 1980	SEPTEMBER 4, 1980
G.M.1	0%	0%	0%	0%	0%
G.M.2	0%	0%	0%	0%	0%
G.M.3	0%	0%	0%	0%	0%
G.M.4	0%	0%	0%	0%	0%
G.M.5	0%	0%	0%	0%	0%
G.M.6	90% Flowing	0%	0%	12.5%	70%
G.M.7				0%	0%
B.H.2 PIEZ I	0%	0%			
B.H.2 S.P. II	0%	0%			
B.H.3 PIEZ. I	0%	0%			
B.H.3 S.P. II	0%	0%			
B.H.3 S.P. III					30%
B.H.4 PIEZ I	0%	0%			
B.H.4 S.P. II	0%	0%			

SECTION E

PRELIMINARY HYDROGEOLOGICAL
STUDY REPORT 78-119 (GLAL)



**Gartner
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Consulting
Engineering
Geologists and
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PRELIMINARY HYDROGEOLOGICAL
INVESTIGATION REPORT
UPPER OTTAWA STREET LANDFILL
FOR
REGIONAL MUNICIPALITY
OF
HAMILTON-WENTWORTH

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FEBRUARY, 1979



**Gartner
Lee
Associates Limited**

Consulting
Engineering
Geologists and
Hydrogeologists

Toronto - Buttonville Airport ■ Markham, Ontario ■ L3P 3J9 ■ 416-297-4600

February 26th, 1979.

Regional Municipality of Hamilton-Wentworth,
Department of Engineering,
City Hall,
Hamilton, Ontario.

Attention: Mr. W. Wheton, P.Eng.
Commissioner of Engineering

Dear Sirs:

Re: Preliminary Hydrogeological Investigation
Report,
Upper Ottawa Street Landfill,
GLAL 78-119

We are pleased to submit our report on the preliminary hydrogeological investigation of the Upper Ottawa Street Landfill, as requested by the Region. The study is authorized by the Region's Purchase Order Number R21723, which is dated November 1st, 1978. The following sections describe the terms of reference for the study, the methodology, study findings, discussion and closure aspects. The conclusions and recommendations are provided at the end of the report. Background data is appended.

A. TERMS OF REFERENCE:

The Upper Ottawa Street Landfill Site will be closed and final rehabilitation measures carried out in the near future. Concerns have arisen with regards to possible leachate migration and methane gas production both now and in the future, their potential impact and the need for mitigating measures.

continued -

The purposes of the present investigation are to identify any existing and/or potential problems related to leachate and methane gas, to define the scope of any concerns and to assess the need for a detailed follow-up programme. Thus the preliminary investigation is of a feasibility and planning nature.

As per the terms of the proposal, dated August 24th, 1978, the study will specifically address the hydrogeological and hydrological setting of the site, the occurrence and nature of any leachate and its potential impact, the potential for off-site gas migration, closure methods and recommendations for further detailed study.

B. METHODOLOGY:

The study was carried out employing an integration of office analysis procedures and field investigation techniques. The office work consisted of a compilation of all available reports and maps of the landfill site and environs and a review of these data. The Ministry of the Environment water well records were searched and relevant data extracted. As well aerial photographs from two time periods, (a) 1954 which documents early landfill site conditions and (b) 1972 which shows the almost developed site, were stereoscopically interpreted to provide further details of the terrain, topography, drainage etc. and to assess landfill development. These data were transposed onto 1:25,000 scale base maps and are filed for future reference.

A ground truth check was then completed to verify the predicted hydrogeological setting i.e. terrain, topography, drainage etc., and to field map surficial features such as leachate springs within the landfill. Due to the preliminary nature of the study, there was no sub-surface drilling.

continued -

Finally all data were collated and analysed, and an engineering report prepared to document the findings.

C. STUDY FINDINGS:




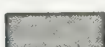
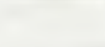


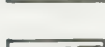
- I. Regional Setting: The Upper Ottawa Street Landfill is situated on the plateau lands above the Niagara Escarpment in an area of shallow glacial till soil over bedrock. Deeper glacial moraine occurs to the north and to the south of the site. The glacial till is predominantly clayey in texture. The bedrock is a limestone-dolomite of the Lockport Formation which forms the caprock of the Escarpment. The rock surface regionally slopes easterly towards the Escarpment but forms a minor valley coincident with Redhill Creek. This valley trends easterly to join a re-entrant feature within the Escarpment below Albion Falls. There is a series of mini scarps, one bordering the site, on these uplands. Plate 1, "Physical Setting" depicts the terrain conditions as described above.

Ground water table geometry within the shallow soil upper rock unit is a subtle reflection of the surface and/or rock topography. Thus there is a component of flow towards the Escarpment face and a component towards the Redhill Creek valley. Redhill Creek is then a discharge zone for ground water i.e. base flow is received from gradients that are upward. A general interpretation of this ground water regime is shown in Plate 2. Most of the lands encompassing the landfill are serviced or are proposed for servicing with municipal water. Consequently there is at this time minimal use of ground water, as a supply. Historically water wells tapped the upper dolomite bedrock which is the aquifer for the area.

Hydrologically, the landfill site is located within the Redhill Creek drainage basin which is about 20 square miles in area. A significant portion of the basin is urbanized, particularly below the Escarpment



Legend

-  Glacial Till - Predominantly Clay
-  Glacial Till - Shallow Over Rock
-  Niagara Escarpment
-  Floodplain - Shallow Alluvial Soil Over Rock
-  Waste
-  Quarry
-  Rock Scarp
-  Surface Drainage Course

Physical Setting I

Preliminary Hydrogeological Investigation
Ottawa Street Landfill
for
Regional Municipality
of
Hamilton Wentworth

1 mile

Project 78-119

Scale 1:25,000





Legend

- 700 Static Water Level Elevation
- 680 — Inferred Equipotential Contour
- Probable Ground Water Flow Direction
- X X X X Landfill Site

Ground Water Regime
Bedrock

2

Preliminary Hydrogeological
Investigation
Ottawa Street Landfill
for
Regional Municipality
of
Hamilton Wentworth

1 mile

Project 78-119

Scale 1:25,000



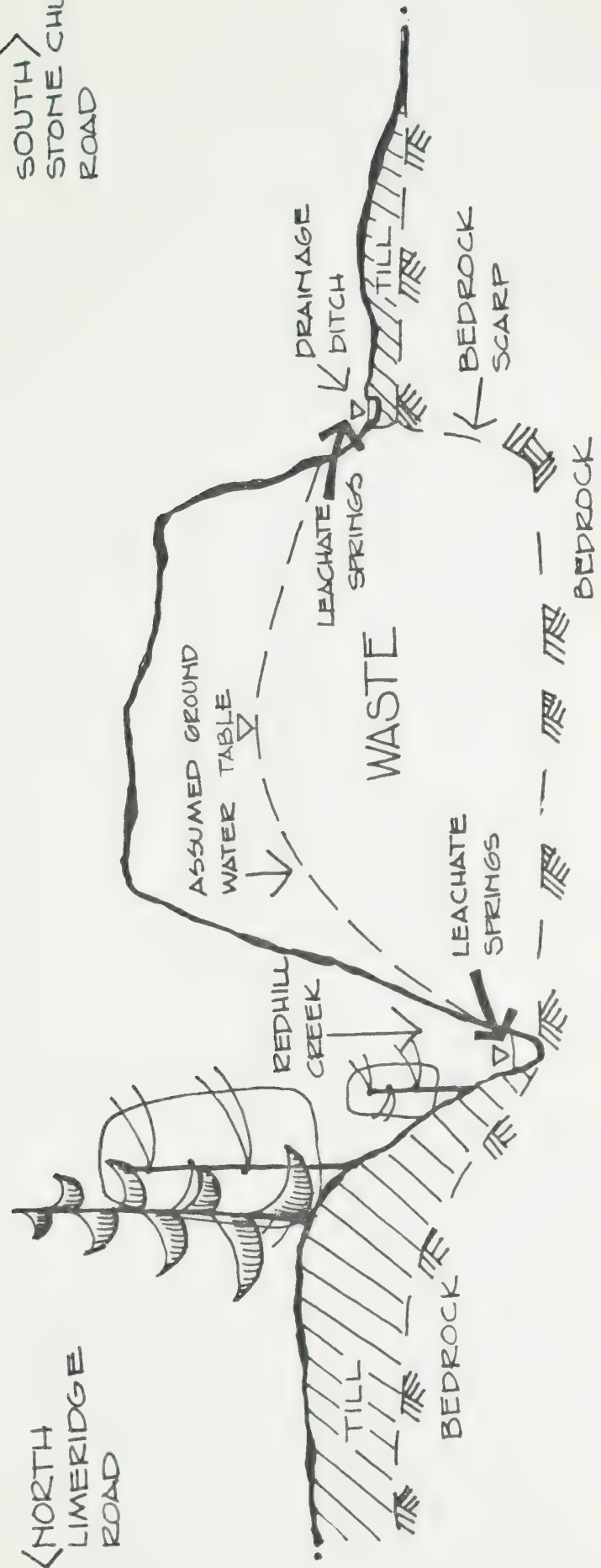
and south and west of the site above the Escarpment. A section of the creek is piped underground just up-gradient from the landfill and it is understood that there may be some sanitary sewer overflows discharging into this piped section of the creek. In the absence of a stream flow gauging station in the basin above the Escarpment, historical flow data is vague. However, the M.O.E. reports base flow (summer flow) in the vicinity of the landfill at about 1 to 2 cubic feet per second (cfs) and at the time of our field check (December 1978), the stream flow was estimated at 3 cfs.

Although there are no apparent direct surface water uses such as fishing, swimming, boating etc., there is an aesthetic value to the creek which flows downstream from the site through park and green belt corridors. There may be a potential for increased future recreational activity depending on water quality management, and development.

- II. Landfill Site: The existing landfill site covers the former Redhill Creek floodplain, parts of the original creek channel and extends south-westerly over an area of shallow glacial drift. There is an indication that the drift was excavated prior to waste disposal. The north edge of the landfill borders the re-located creek which is confined by naturally steep valley walls of the till moraine on the north and the waste itself on the south. Bedrock is visible locally in the creek bed. Along the south-westerly edge, the wastes are contained by a bedrock scarp. On the south and west sides, the landfill site abuts transportation corridors. Based on contour maps, the waste in 1978 was in the order of 70 feet deep, over the bedrock so that the upper surface of the fill is well above the surrounding terrain. Sketch 1 and 2 illustrates schematically the hydrogeological setting of the site and environs.

continued -

SOUTH
STONE CHURCH
ROAD

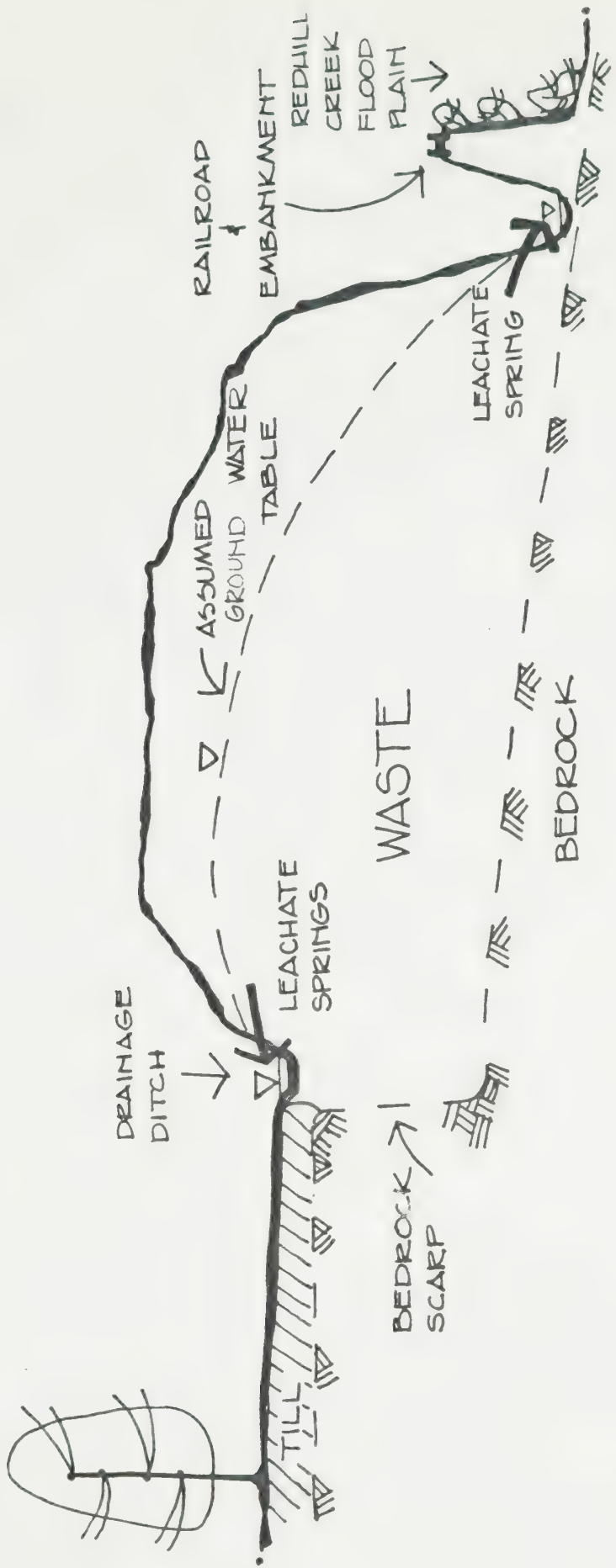


NOT TO SCALE

SKETCH 1

WEST
UPPER OTTAWA STREET

EAST



SKETCH 2

NOT TO SCALE

There is an indication that the ground water table has mounded within the waste. Ground water mounding occurs in a waste disposal site when the rate of water and/or fluid infiltration exceeds the rate of exfiltration from the base. Leachate springs are present around the perimeter of the site, and this suggests that the elevation of the water table is higher than the surrounding lands. Also, some of the springs may reflect a perched water condition.

Leachate springs are visible about 10 to 15 feet above the toe of the waste along the south and west perimeter fill face. The leachate collects in a ditch and flows to a sewer inlet at the south-east corner of the site. It is estimated that the rate of leachate egress is to the south-east at 2 to 4 gallons per minute (gpm). Although there were no obvious springs visible along the major portion of the creek, at the time of the site visit it is probable that leachate does discharge directly into the creek, below water level. As well there are leachate springs emanating at the toe of the waste along the north half of the east perimeter. These springs collect and flow directly into the creek. The estimated total discharge rate of leachate springs is 6 to 10 gpm.

The chemical composition of the leachate was analysed by M.O.E. and a summary of the results are appended in Table 2.

III Water Budget: The water budget for this site was calculated from the 20 year normal climatological conditions as recorded at the Mount Hope Airport. For the determination of the potential evapotranspiration, the Thornthwaite method of analysis was employed. Following is a summary of the detailed results presented on Table 1 in the Appendix:

continued -

Average Annual Mean Precipitation	31.3 inches
Average Annual Potential Evapotranspiration	<u>24.2</u> inches
Average Annual Potential Surplus	7.1 inches

Since the actual evapotranspiration is normally ± 4 inches lower in this area than the estimated potential, then the actual water surplus is about 11 inches per year.

During the operation of the facility, leachate is being generated from rainfall infiltration at the estimated rate of about 0.5 gallons per minute per acre (± 12 inches per year) or about 30 gpm. Liquid industrial waste which is being dumped on the site contributes an additional ± 5 gpm, (based on data published by the M.O.E.).

D. DISCUSSION:

Field observations confirm that the Upper Ottawa Street Landfill is generating leachate. The leachate is the consequence of natural infiltration of rainwater percolating through the waste and liquid industrial wastes (both treated and untreated) disposed of on the site. Estimates indicate that about 6 to 10 gpm of leachate emanate as surface springs. Since the estimated rate of total leachate production is about 35 gpm., it may be concluded that the difference - about 70 to 80% exfiltrates through the base and is retained in the waste. We feel that the portion of leachate retained in the waste is probably, relatively small due to the age of the fill and its past history. Thus the waste is probably at or near field capacity; however, subsurface data would be needed to confirm this.

The leachate, after it enters the ground water flow system in the bedrock, is suspected to migrate via hydraulically connected structural features (joints, bedding planes etc.) in response to ground water pressure gradients. The regional flow system as depicted on Plate 2, "Ground Water Regime, Bedrock", would indicate that the general direction of

continued -

leachate movement may be in a north-easterly direction and may be confined to the creek valley. Although there is a potential for leachate migration, there is no available subsurface information to date to verify or assess such movement. In order to evaluate quantitatively the degree of potential impact, a detailed site investigation programme, involving borehole drilling, water pressure monitoring and chemical analysis would be necessary.

Leachate is entering the waters of Redhill Creek via overland flow. Based on M.O.E. water chemistry monitoring information in their report "The effects of the Upper Ottawa Street Landfill on Redhill Creek, 1978", the landfill appears to be responsible for only minor chemical effects on the creek. Indeed, rough mass balance calculations assuming average flow and water quality conditions of the leachate and stream and using the conservative chloride ion, verified these present-day conclusions. However, our experience has shown that traditional water chemical parameters often may not indicate an effect although stream water may give off obnoxious odours and the stream bottom may be fouled by sewage fungus and stained by iron deposits. To determine these effects and possible effects on the aquatic life associated with the stream substrate, such water quality studies should include a survey of bottom fauna populations. As well, there is a potential for increased future loadings related to the discharge of contaminated ground water into the creek. It should be noted that the sewers, road salt and other land contaminant run-off up-gradient of the site is influencing the background quality of the water prior to flowing past the site. In order to properly assess the existing situation and to estimate the potential impact, further detailed water budget and stream input, and physical and biological studies are required.

All landfills produce gases as waste decomposes of which methane is of most concern. This gas will only migrate through a porous or fractured and unsaturated medium. Since the water table is mounded within the waste, the existing potential for lateral movement of gas beyond the waste appears negligible. As well the creek to the north and the wetlands to the east represent boundary conditions which will arrest lateral migration. However, if water levels recede in the future after site closure, there is a potential for lateral movement through rock to the west and south. Consequently gas monitors should be installed in this area and checked for gas on a regular basis.

E. CLOSURE ASPECTS:

From a general viewpoint, closure procedures should include placing final clay cover 3 to 5 feet deep, contour grading and vegetation to reduce infiltration and thus minimize the generation of leachate. These measures will also assist in controlling surface run-off and erosion. Since the north face of the landfill is particularly susceptible to erosion by the creek waters, erosion control measures such as gabions or rip-rap should be considered.

Leachate springs are contributing to the degradation of water quality in Redhill Creek as well as creating a negative visual impact around the site and will require rehabilitation. In this regard remedial work may involve the physical collection of the leachate by a system of toe drains and cosmetic control employing a granular blanket along the slopes. Based on the preliminary study results, toe drains would probably be most effective along the south and west periphery and the granular blanket concept in other areas of leachate spring production. The design of such systems would be subject to additional hydrogeological/geotechnical field data.

Total control or complete collection of leachate within the bedrock environment will be difficult and costly, if leachate exfiltration and migration are confirmed in detailed studies, as a problem. One possible system of collection is purge wells. Extensive hydrogeological data would be required to design the system, it would be costly to construct, there would be long-term operation and maintenance concerns and finally the leachate would have to be disposed of. The most practical approach to off site migration may be to allow the migration but to be aware of the problem and its magnitude and to monitor. This approach must be approved by the Ministry of the Environment.

As part of the closure procedure, a gas venting system should be installed within the waste. At this time, gas migration off-site is not a concern. However monitors should be installed to measure any future changes. If shown necessary a gas venting system could be constructed.

continued -

F. CONCLUSIONS AND RECOMMENDATIONS:

The study shows that the Ottawa Street Landfill is in a poor hydrogeological setting for waste disposal, i.e., it is located in an area of thin soil cover underlain by permeable bedrock, with surface waters almost in contact with the waste.

Based on a preliminary water budget analysis we conclude that the refuse is producing leachate and about 20% of the total emanates as springs around the perimeter of the fill. The remaining 80% of the contaminated fluid is being absorbed by the waste itself and is being ex-filtrated into the subsurface ground water environment. Unfortunately, there is a lack of subsurface information and observation points. The assessment of leachate aspects now and in the future cannot be confirmed or predicted at the present time.

The water quality of Redhill Creek has been reported upon recently by the Ministry of the Environment (M.O.E.) from a chemical point of view. These data show minimal adverse effects at the present time. Future impacts and bio-physical effects cannot be assessed with the existing data.

The landfill is also producing gases as it decomposes, one of which is methane. Migration of gas beyond the fill in the subsurface is highly unlikely at present because of the hydrogeological boundary conditions. However, if water table conditions change in the future there may be a potential avenue for lateral movement of gas to the south and west.

Based on the foregoing we submit the following recommendations for your consideration.

- 1) A detailed sub-surface leachate and gas migration study should be considered. A leachate study would involve the investigation of quantity, quality, migration patterns and extent as well as impact aspects now and in the future. It should also

consider monitoring and remedial measures based on the findings. Such a programme would involve subsurface drilling, monitor installations and laboratory testing to provide data for analysis. Details of this type of programme are being transmitted under a separate cover for your reference.

The complex hydrogeologic setting, i.e. flow in fractured rock, will create a high degree of difficulty for successfully tracing the leachate and analysing it quantitatively and accurately. The cost-benefit - liability aspects should be weighed carefully.

- 2) If further study and monitoring of Redhill Creek are to be carried out these should include biophysical aspects. This could be incorporated into 1) above. Actual flow data should be developed if this proceeds so that contaminant loadings can be accurately calculated.
- 3) It is recommended that gas monitors be installed near the perimeter of the fill to the south and west. A proper monitoring programme should be set up.
- 4) The site should be properly closed according to the guidelines of section E, as soon as practical.
- 5) The study findings should be reviewed by the Ministry of the Environment.

Page 11.
Regional Municipality of Hamilton-Wentworth,
February 26, 1979.

We thank you for the opportunity to assist you in successfully closing the Upper Ottawa Street Landfill.

Yours very truly,

GARTNER LEE ASSOCIATES LIMITED

D. E. Jagger, P.Eng.,
Senior Project Engineer.

P. K. Lee, M.A.Sc., P.Eng.,
Consulting Engineering Geologist.

DEJ:jcm

APPENDIX

TABLE 1
WATER BUDGET SUMMARY
(20 YEAR NORMAL)

MONTH	MEAN PRECIPITATION	POTENTIAL EVAPOTRANSPIRATION	WATER EXCESS	WATER DEFICIT
	inches	inches	inches	inches
January	2.67	0	2.67	
February	2.09	0	2.09	
March	2.21	0	2.21	
April	3.21	1.37	1.84	
May	2.53	2.98		0.45
June	2.24	4.55		2.31
July	2.83	5.18		2.35
August	2.80	4.68		1.88
September	2.89	3.15		0.26
October	2.66	1.76	0.9	
November	2.85	0.48	2.37	
December	2.36	0	2.36	
	<hr/> 31.34	<hr/> 24.2	<hr/> 14.44	<hr/> 7.25

Note:

Climatological Station Located at the Mount Hope Airport

TABLE 2
CHEMICAL NATURE OF LEACHATE*

PARAMETER	M.O.E.** STANDARD	LOCATION OF SPRING		
		SOUTH FACE (Stone Church Rd.)	NORTH FACE (Creek)	EAST FACE (Railroad)
Suspended Solids	-	199	430	166
Total Solids	500	8,000	8,600	10,950
Turbidity	-	23	8.2	42.9
Chloride	250	2,800	1,811	2,920
Alkalinity	-	3,670	4,840	4,170
pH	6.0-8.5	8.4	7.9	8.0
Conductivity (umhos/cm)	-	11,450	12,100	16,200
BOD ₅	-	110	280	121
COD	-	1,200	2,660	1,630
Free Ammonia	0.5	120	450	263
Total Kjeldahl	-	147	657	323
Nitrite	10	.12	.09	.08
Nitrate	10	.12	.15	.12
Total Phosphorus	-	2.06	10.1	2.7
Soluble Phosphorus	-	.46	4.6	1.04
Cadmium	.01	.008	.008	.008
Copper	1.0	.072	.048	.095
Lead	.05	.554	<.06	<.06
Nickel	-	.245	.150	.06
Zinc	5	.694	.295	.330

* Extract - M.O.E. Report "The Effects of the Upper Ottawa Street Landfill on Redhill Creek", November, 1978.

** 1973 Published Guidelines for public surface water supplies.
All concentrations in mg/l unless otherwise noted.



LEGEND

- BH1**
● GARTNER LEE BOREHOLE LOCATION AND DESIGNATION
- GM1**
◆ GARTNER LEE GAS MONITOR LOCATION AND DESIGNATION
- SW1**
■ SURFACE WATER MONITORING STATION AND DESIGNATION
- A**
↗ CROSS-SECTION
- EXISTING WATERMAIN NETWORK
- - - PROPOSED WATERMAIN NETWORK
- IRM**
⊕ MINISTRY OF THE ENVIRONMENT SURVEY WELL

NOTE: Base map derived from 1978 aerial photography, N.T.S. contour mapping and the Upper Ottawa Street Landfill. Base plan dated April 1976.

This plan has been prepared for presentation purposes only, and locations may vary slightly from the history drawings.

CABON-6390
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URS H.W.

Site Plan

1

Detailed Sub-Surface Leachate
And Gas Migration Study
Upper Ottawa Street Landfill Site
for
Regional Municipality Of
Hamilton - Wentworth









PROJECT 79-78
SCALE 1:4,000



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LEGEND

-  GLACIAL TILL - lacustrine over bedrock
-  GLACIAL MORaine Till - lacustrine complex
-  WASTE
-  ESCARPMENT LANDS
-  BOTTOM LANDS
-  ROCK SCARP
-  QUARRY PITS
-  SURFACE DRAINAGE COURSE

N.T. Base map derived from 1978 aerial photography, N.T.O. contour mapping and the Upper Ottawa Street Landfill base map dated April 1976.

Geological boundaries are inferred and may differ from those shown.

CA30N46290 uro/hw
80494

Physical Setting 2

Detailed Sub-Surface Leachate
And Gas Migration Study
Upper Ottawa Street Landfill Site
for
Regional Municipality Of
Hamilton - Wentworth

PROJECT 79-78
SCALE 1:4,000



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LEGEND

- 600 INFERRED BEDROCK CONTOUR
- 590.2 OBSERVATION POINT AND BEDROCK ELEVATION

NOTE: Data was derived from 1978 aerial photography, NTS contour mapping and the Upper Ottawa Street Landfill base map dated April 1978.

CA30NH/WG90
80/H94
u&g/rum

Bedrock Topography 3

Detailed Sub-Surface Leachate
And Gas Migration Study
Upper Ottawa Street Landfill Site
for
Regional Municipality Of
Hamilton - Wentworth

PROJECT 79 78
SCALE 1:4,000

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LEGEND

- 610 INFERRED GROUND WATER TABLE CONTOUR (June 1980)
- ➔ PROBABLE SHALLOW GROUND WATER FLOW DIRECTION
- 6367 OBSERVATION POINT AND WATER TABLE ELEVATION (June 1980)

NOTE: Base map derived from 1978 aerial photography, NTS contour mapping and the Upper Ottawa Street Landfill base plan dated April 1976.

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Water Table 4

Detailed Sub-Surface Leachate And Gas Migration Study
Upper Ottawa Street Landfill Site for
Regional Municipality Of
Hamilton - Wentworth

PROJECT 79.78
SCALE 1:4,000

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Lee
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Limited



LEGEND

- 600 INFERRED POTENTIOMETRIC GROUND WATER CONTOUR (June 1980)
- ➔ PROBABLE GROUND WATER FLOW DIRECTION IN ROCK
- 608.4 OBSERVATION POINT AND POTENTIOMETRIC ELEVATION (June 1980)

NOTE: Base map derived from 1978 aerial photography, NTS contour mapping and the Upper Ottawa Street Landfill base plan dated April 1976.

CASON HW 890
80494 *URS/hwl*

Potentiometric
Surface

5

Detailed Sub-Surface Leachate
And Gas Migration Study
Upper Ottawa Street Landfill Site
for
Regional Municipality Of
Hamilton - Wentworth

PROJECT 79-78
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